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AND

UNIVERSITY PAPERS

WITH

ANSWERS

CALCUTTA
CHAKRABURTTY, CHATTERJEE & CO.
15, College Square.

PUBLISHED BY B. C. DE

31, Durga Charan Mittra Street, Calcutta.

Printed by J. C. Adhikari,

METCALFE PRESS

76, Balaram De' Street, Calcutta.

PREFACE.

The book has been written to remove the long-felt want of a suitable book of Examples in Physics for the students of our Intermediate Course. As the books already existing in the field have not evidently been written with a view to the special requirements of our students, we bring out this publication compiled by authors of long experience.

In the preparation of the book care has been taken to select examples which are at once instructive, typical and important, judged from the nature of the problems set in the University Papers. A special feature of the book is that problems of every possible variety have been given either a complete solution or direct hints to that effect to guide the students.

Further, explanatory notes have been inserted by way of helping the memory of a student in the proof of an important formula which he has culled from the text books.

To make the publication the more useful, we have inserted the University Intermediate Questions in Physics with their Answers. The latter has been arranged in a way as not to render full help to the student but just to give him sufficient scope in exercising his own intelligence in trying to find the full answers. For the covenience of the students the subject-matter of each question has been shown in the margin, morever, in cases where a question has been repeated, the year, the paper and the question

number of such repititions have also been put in the margin, from which the student will be able to realise for himself the importance of a question.

In conclusion, it may be confidently said that a student, in going through the book, will be able to save much of his time and trouble and will be fully competent to answer problems of any type set in the University examinations,

January 1, 1916,
CALCUTTA.

THE PUBLISHERS.

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EXAMPLES IN PHYSICS.

CHAPTER I.

Pendulum.—The formula that holds in the case of a simple pendulum is

$$t = 2\pi\sqrt{\frac{l}{g}}$$

where t=time of a complete oscillation in seconds
l=length of the pendulum
and g=acceleration due to gravity.

A *seconds* pendulum is one which makes half a complete vibration in a second

$$i.e. \quad 1 = \pi\sqrt{\frac{l}{g}}$$

1. The value of g at a place is 981 cm. per sec. per sec. Find the length of the seconds pendulum.

Let l=required length of pendulum,

then $$1 = \pi\sqrt{\frac{l}{g}} = \pi\sqrt{\frac{l}{981}}$$

$$\therefore \quad 1 = \pi^2 \frac{l}{981}$$

$$\therefore \quad l = \frac{981}{\pi^2} = \frac{981}{9{\cdot}87} = 99{\cdot}39 \; cm.$$

2. Show that in a place where $g=987$, a pendulum would beat seconds if its length were 1 metre.

3. If $g=32\cdot2$, what is the length of a pendulum vibrating in $2\cdot5$ seconds ?

4. A pendulum is 7 feet in length and it makes 10 complete oscillations in 20 seconds. Find the value of g at the place.

5. Find the value of g at the top of a mountain where a pendulum, constructed to beat seconds at a place where $g=950$, has to be shortened $\frac{3}{19}$ ths of its original length in order to make it beat seconds.

$$\textit{Hints}:— \quad 1=\pi\sqrt{\frac{l}{950}}=\pi\sqrt{\frac{l\frac{3}{19}}{g'}}$$

6. The length of a seconds pendulum is $39\cdot2$ in, find the lengths of the pendulums which will vibrate in $\frac{1}{4}$ sec and in 2 secs.

7. Find the length of a pendulum which will oscillate 56 times in 55 seconds.

$$\textit{Hints}:— \quad t=55/56=2\pi\sqrt{l/g}=2\pi\sqrt{l/32}$$

whence $l=37\frac{1}{2}$ in.

8. How many oscillations will a pendulum of length 4ft. make in one day ?

$$\textit{Hints}:— \quad t=2\pi\sqrt{l/g}=2\pi\sqrt{4/32\cdot2}$$

$\therefore$ The number of oscillations in a day (86400 secs.) is given by $n=\dfrac{86400}{t}$.

9. A faulty seconds pendulum loses 9 seconds per day; find the required alteration in its length, so that it may keep correct time ?

1 day=86400 seconds.

Since the pendulum loses 9 seconds per day, it beats (86400-9) or 86391 times per day i.e., in 86400 seconds, so that its time of oscillation is 86400/86391 second (and not 1 second as it ought to be).

Let l be its length

$$\therefore \quad \pi\sqrt{\frac{l}{g}}=\frac{86400}{86391} \quad \ldots \quad \ldots (1)$$

Let its length be changed from l to $l+x$ to make it keep correct time; since, in that case, it becomes a true seconds pendulum, its time of oscillation becomes 1 second.

$$\text{hence, } \pi\sqrt{\frac{l+x}{g}} = 1. \qquad \ldots \qquad (2)$$

$$\text{From (1) and (2) } \pi^2\frac{l}{g} = \left(\frac{86400}{86391}\right)^2 \text{ and } \pi^2\frac{l+x}{g} = 1.$$

$$\text{Subtracting } \pi^2\frac{x}{g} = 1 - \left(\frac{86400}{86391}\right)^2$$

$$= 1 - \left\{1 + \frac{9}{86391}\right\}^2$$

$$= 1 - \left\{1 + \frac{18}{86391} + \text{etc.} \ldots\right\}$$

by the Binomial theorem.

$$= -\frac{18}{86391}.$$

$$\therefore \quad x = \frac{g}{\pi^2} \times \left(-\frac{18}{86391}\right) = -\frac{32 \times 7^2}{22^2} \times \frac{18}{86391}$$

$$= -\cdot 008 \text{ in.}$$

Hence the length of the pendulum must be *shortened* by ·008 in.

10. A faulty seconds pendulum loses 20 secs. per day. Find the alteration in its length so that it may keep correct time.

CHAPTER II.

HYDROSTATICS.

In solving examples, the following facts may be noted :—

The mass of a cubic foot of water is 1000 ounces or 62·5 pounds.
Cross-section of a cylinder of radius r is πr^2
Area of the surface of a sphere of radius r is $4\pi r^2$.
The volume of a sphere is $\frac{4}{3}\pi r^3$.

Density.—The density (ρ) of any body is given by the formula—

$$\rho = \frac{M}{V} \quad \text{where}$$

M=mass of the body,
V=Volume „ „

1. A sphere 20 cms. in radius has a mass of 10 kilograms Find its density ?

Density of a body is given by the formula :—

$$\rho = M/V$$

$$= M/\tfrac{4}{3}\pi r^3 = \frac{10 \times 1000}{\frac{4}{3} \times \frac{22}{7} \times 8000} = 0{\cdot}29 \textit{ gms per c.c.}$$

2. A piece of metal weighs 40·5 kilograms and its volume is 15000 *c.c.* Find its density ?

3. Find the density of a substance which is five times as heavy as water. Give your answer in ounces per cubic in.

4. A tank is 8 by 4 by 10·5 cm. What weight of water can it hold ?

5. Find the weight of a litre of mercury. (Density of mercury =13·6 gms / cc

6. A capillary glass tube weighs ·2 gm. A thread of mercury 10 cms. long is drawn into the tube when it is found to weigh ·6 gm. Find the diameter of the capillary tube.

Hints ;—Wt. of mercury$=\pi r^2 \cdot 10.\rho=(\cdot 6-\cdot 2)$ gm. Hence $2r$.

7. The mass of 10 *cub. ft.* of a metal is 800 *lbs.* Find its density in gms. per c.c.

1 *lb.*=453·6 gms. and 1 *cub. ft.*=28315 *c c.*

$$\text{Hence } \rho=M/V=\frac{800\times 453\cdot 6}{10\times 28315}=1\cdot 28 \text{ gms per } c.c.$$

8. Iron has a density of 7.76. Find the weight of 100 cub. ft. of iron.

9. Density of glass is 2·5. Find what volume weighs 4.25 gms.

10. A body weighs 500 lbs. and its density is 4. Find its volume ?

11. A flask when empty weighs 120 gms. when full of air it weighs 121 3 gms. and when full of water 1220 gms : calculate the density of water.

Fluid Pressure—The intensity of pressure at a point A *i.e.* the pressure per unit area round A at a depth h below the surface of a liquid of density ρ (neglecting the atmospheric pressure) is given by

$$p=g\rho h.$$

If the atmospheric pressure is taken into account the pressure at A is given by

$$p=g\rho h+\pi.$$

where π is the atmospheric pressure on unit area of the surface of the liquid.

12. Find the pressure due to a column of mercury 50 cms high. Does the pressure vary with the diameter of the tube in which the mercury is made to stand ?

$$\begin{aligned}\text{we have } p&=g\rho h\\ &=981\times 13\cdot 6\times 50, \text{ taking } g=981.\\ &=0\cdot 667\times 10^6\ dynes.\\ &=0\cdot 667\ megadynes.\end{aligned}$$

13. Distinguish between pressure and intensity of pressure.

14. What must be the height of a column of water in order that the pressure at its base may be equal to 10^6 dynes per sq. cm.

15. The density of sea water is 1.025. Find the pressure at a depth of 10 feet below the surface in pounds per sq. ft.

Here volume of water on an area of 1 sq. ft. = 10 cub. ft

1 cub. ft. of water weighs—62·5 lbs.

" " sea-water " —$6.25 \times 1·025 = 64·06$ lbs.

10 " " " " — $10 \times 64·06 = 640·6$ lbs.

and this is the pressure per sq. ft.

∴ 10 cub. ft. of sea-water weighs—$10 \times 64·06 = 640·6$ lbs. and this is the pressure per sq. ft.

16. A horizontal area of 2 sq. cms. is sunk to a depth of 20 cms. below the surface of a liquid of density 0.55. Find the pressure in gms. wt.

17. A laboratory is supplied from a tank at a height of 60 ft. Determine the available water pressure ?

18. Find the pressure at the bottom of a pond 15ft. deep, the atmospheric pressure being 15 lbs per sq. inch.

19. To what depth must a circular disc 16 cms. in diam. be sunk in mercury (density 13.6) in order that the pressure on it may be 68,360 gms. ?

20. A cube, the edge of which is 10 cms. is suspended in water with its sides vertical and its upper surface at a depth of 10 cms. below the surface. Find the pressure on each of its faces ?

21. Prove that a body immersed in a liquid sustains an upward pressure which is equal to the weight of the displaced liquid.

22. Describe how you would demonstrate experimentally the truth of the principle of Archimedes and explain what is meant by the apparent weight of a body in water.

23. State the condition of floatation of a body immersed in a liquid.

24. What volume of water will be displaced by a block of wood of 500 gms weight. The specific gravity of wood is 0.65.

25. A piece of cork of mass 100 gms and density 0.25 floats in a vessel full of water. Find how much water overflows ?

26. A lump of copper weighing 16 ozs. is placed in a tumbler and causes 1·8 ozs. of water to overflow. Calculate the specific gravity of copper.

27. The specific gravity of sea-water is 1·028 and that of ice is ·918. What fraction of the volume of an ice-berg floats out of water?

Let V=total vol. of the ice-berg.

V^1=volume outside the water.

According to the condition of floatation,

Weight of ice-berg=upward pressure of the displaced liquid.

$$i.e.\ V \times \cdot 918 = (V - V^1) \times 1 \cdot 028$$

$$\text{whence, } \frac{V^1}{V} = \frac{1028 - 918}{1028} = \cdot 107.$$

28. An ice-berg floats with only 500 cubic yards exposed. Find its total volume? The specific gravity of ice is 0·918 and that of sea-water is 1·035.

29. A piece of wood weighing 20 gms. floats in water with $\frac{1}{4}$th of its volume immersed. Find the density and the volume of the wood?

30. A piece of wood of specific gravity 0·5 is floating in oil of specific gravity 0·8. Find the fraction of its volume immersed?

31. A block of wood 10 lbs. wt. floats in a liquid with $\frac{1}{3}$rd of its volume above the surface. What weight must be placed on the block in order just to sink it?

32. Determine the position of equilibrium of a sphere of glass (density 2·8) which is dropped into a vessel containing mercury and and water. (Density of mercury is 13·6.)

Let V be the volume of the sphere and V' the portion of its volume immersed in mercury.

Then $(V - V')$ of the volume of the sphere is in water.

$$\therefore\ V \times 2 \cdot 8 = V' \times 13 \cdot 6 + (V - V') \times 1.$$

$$Or\ V \times 1 \cdot 8 = V' \times 12 \cdot 6.$$

Hence $V'/V = \cdot 143$. or the sphere will rest in equilibrium with only ·143 part of its volume immersed in mercury.

Atmospheric Pressure—

If π denotes the atmospheric pressure in dynes per sq. cm.

then $\pi = h\rho g$.

where, h is the barometric height
ρ ,, ,, density of mercury (= 13·596)
g ,, ,, acceleration due to gravity.

The normal atmospheric pressure *i.e.* that due to the barometric height of 76 cms. is given by

$$\pi = 76 \times 13.596 \times 981 = 1,013,663 \text{ dynes.}$$

In order to express the atmospheric pressure in gms. weight per sq. cm.—we consider a barometric pressure due to a column of mercury 76 cms. high and 1 sq. cm. cross-section—this quantity of mercury occupies 76 *c.c.*

Now, 1 *c.c.* of water weighs 1 gm.
∴ 76 ,, ,, 76 gms.
Hence ,, ,, mercury ,, 76 × 13.596 gms
= 1033 gms.

Thus the pressure is equal to a weight of 1033 gms per sq. cm.

Again to express the atmospheric pressure in pounds per sq. inch,—we consider a barometric column 30 inches high and 1 sq. cm. cross-section; this column occupies a volume of 30 cub. inches.

Now 1 cub. ft. of water weighs 62.5 lbs.

∴ 1 cub. inch ,, ,, $\frac{62.5}{1728}$ lbs.

and ,, ,, mercury ,, $\frac{62.5}{1728} \times 13.596$ lbs.

∴ 30 ,, ,, ,, ,, $\frac{62.5}{1728} \times 13.596 \times 30$

$= 14.75$ lbs.

Hence, the atmospheric pressure is equal to a weight of 14.75 lbs. per sq. inch.

33. Deduce the pressure per sq. cm., corresponding to a barometric height of 70 cms.

Quantity of mercury in a column 70 cms high and 1 sq. cm area $=70 \times 1$ c.c.

But weight of 1 c.c. of water $=1$ gm.

$\therefore$ Wt. of 1 c.c. of mercury $=13.6$ gms.

$\because$ Wt. of 70 cc. of mercury $=70 \times 13.6$ gms. $=9520$ gms.

$\therefore$ Pressure required $=$ wt. of 9520 gms of mercury per sq. cm.

Otherwise thus ;—$p=gph$

$$=981 \times 13.6 \times 70 \text{ dynes}$$
$$=9.34 \times 10^5 \text{ dynes per. sq cm.}$$

34. The height of water-barometer is 30 ft. Deduce the value of the atmospheric pressure in ounces per square foot.

35. What is the height of a water barometer when the mercury barometer reads 20 inches ?

36. Density of glycerine is 1.27. Find the height of a glycerine barometer when the water barometer stands at 25.4 ft.

37. What change in the atmospheric pressure on a square inch is indicated by a fall of 1 inch in the height of the barometric column.

38. State Boyle's Law, and explain it ? What is the relation between the density and pressure of a gas ?

39. The volume of a quantity of gas is measured when the barometer stands at 70 cms. and is found to be 760 cc. What will be its volume at normal pressure ?

Normal pressure $=$ weight of 76 cms. height of mercury.

Now apply Boyle's Law $PV=P'V'$.

Here $P=76$, $P'=70$ and $V'=760$

$\therefore$ we have $V=\dfrac{70 \times 760}{76}=700$ c.c.

40. Find the pressure at which the gas in the preceeding question will occupy a volume of 532 c.c.

41. At a pressure of 78 cms. a quantity of hydrogen measured 100 cc. Find the pressure when the volume is increased to 150 cc.

42. At 76 cms pressure one litre of air weighs 1.3 gms. What will be the weight of air contained in a litre flask when the barometer reads 80 cms ?

At 76 cms. pressure 1 litre at 80 occupies a volume

$=\frac{80}{76}$ litres (from Boyle's Law).

∴ Its weight $=\frac{20}{19}\times 1{\cdot}3=1{\cdot}37$ gms. approx.

43. A uniform tube closed at the top, open at bottom is plunged into mercury, so that it contains 25 cc. of gas at an atmospheric pressure of 76 cms ; the tube is now raised until the gas occupies 50 cc. How much has it been raised ?

44. The volume of an air-bubble increases six-fold in rising from the bottom of a lake. Find the depth of the lake—the barometer reading 70 cms. (Density of mercury = 13.6).

Pressure at the bottom of the lake—

= atmos. press. + press. due to h depth of water

= wt. of 70×13.6 cm. of water + wt. of h cm. of water

= wt. of $(70\times 13.6+h)$ cm. of water

From Boyle's Law

$$(70\times 13.6+h)\ V=70\times 13.6\times 6V.$$

whence $h=46.2$ metres.

45. An air-bubble at the bottom of a pond 15 ft. deep has a volume equal to 1/1000 of a cubic inch ; find its volume when it reaches the surface, the height of water—barometer being 30 ft.

46. A quantity of air 3 cc. in vol. and at atmospheric pressure is introduced into the space above a barometric column which originally stands at 760 *m.m.* The column is depressed by 190 *m.m.* Find the volume occupied by the air ?

Hint—Apply Boyle's Law.

$$V_1P_1=V_2P_2.\{i.e.\ 3\times 760=V_2(760-190)\}$$

47. A barometer tube of uniform bore is 34 in. long. A small quantity of air is left in the tube above the mercury, so that the barometer registers 30 in. when the true atmospheric pressure is 30.05 in. What will be the true barometeric reading when this barometer registers 28 in ?

(i) Initially—volume V_1 of enclosed air is $(34-30)=4$ units.

This is at a pressure $P_1=(30.05-30)=.05$.

(ii) Finally, the volume is $(34-28)=6$ units,

and is at a pressure$=P_2$ (say,)

$$\therefore \quad V_1P_1=V_2P_2$$

$$Or \; 4\times.05=6P_2. \quad \text{whence } P_2=.0\dot{3}$$

This is the pressure of air enclosed.

$\therefore$ True barometric pressure$=28+.03=28.03$ in.

48. Distinguish between density and specific gravity of a body.

Express the specific gravity of lead both in the *C. G. S.* and *F. P. S.* systems.

49. A ton of metal occupies a volume of 10 cub. ft. Find its specific gravity referred to water as the standard substance ?

1 ton$=$2240 lbs.

The mass of a cub. ft. of the metal is, $(2240\div10)$ lbs.

and the mass of a cub ft. of water is 62.5 lbs.

Hence the required specific gravity (which is the ratio between the masses of equal volumes) is,

$$224\div125/2=448/125=3.58.$$

50. A cylindrical glass tube has a length of 21 cms. and its internal diameter is 0.8 cm. Find how many grammes of mercury will be required to fill the tube

Mass of mercury in the tube

$$=V\rho=\sigma l\rho \text{ where } \sigma=\text{cross-section of the tube.}$$

$$=\tfrac{22}{7}\times0.16\times13.6.$$

$$=143.6 \text{ gms.}$$

51. The internal diameter of a cylinder is 2 cms. its length is 2 metres and its weight when empty is 175 gms, when filled with a liquid it weighs 285 gms. Find the specific gravity of the liquid.

52. 2 litres of a liquid of specific gravify 0.5 is mixed with one litre of another liquid of specific gravity 1.5 and the mixture occupies half the volume of its components. Find the specific gravity of the liquid ?

The volume of the mixture is $\tfrac{1}{2}\times3000=1500$ c c.

If ρ is the density, the mass of the mixture in gms. is

$$V\rho = 1500 \times \rho \text{ gms.}$$

$$\therefore \quad 1500 \times \rho = (1000 \times 1.5) + (2000 \times 0.5)$$

$$= 1500 + 1000 = 2500 \text{ cc.}$$

Thus $\rho = 2500/1500 = 1.6.$

53. Equal weights of two liquids of specific gravity 0.2 and 0.3 are mixed together and a contraction of 5 per cent. occurs in the volume. What is the specific gravity of the mixture ?

54. A mixture is made of 7 c.c. of a liquid (specific gravity 1.85,) and 3 c.c of water. The specific gravity of the mixture is found to be 1.615, Determine the amount of contraction ?

55. If the specific gravities of two liquids be 2 and 3 respectively find the specific gravity of a mixture containing 7 parts by volume of the former to 3 parts by volume of the latter.

Total vol. = 10.

mass of 1st $= (7 \times 2) = 14$

,, ,, 2nd $= (3 \times 3) = 9$

Total mass = 23.

Hence $\rho = 23/10 = 2 \cdot 3.$

56. Equal volumes of three liquids are mixed together. The first has a specific gravity 2. that of the second is 3 and the specific gravity of the mixture is 2.6. Find the specific gravity of the third.

57. Two liquids have specific gravities 2 and 3 respectively. 7 parts by weight of the former is mixed with 3 parts by weight of the latter. Find the specific gravity of the mixture ?

58. A body weighs 20 gms in vacuo and 15 gms. in water. Find its volume and specific gravity.

Loss in wt. = weight of displaced water

(by Archimedes, Principle)

$= (20 - 15)$ gms $= 5$ gms.

$\therefore$ Vol. of body = 5 c.c.

Specific gravity = 20/5 = 4.

59. Find the apparent weight of a substance (density 2) in water which weighs 10 gms. in vacuo.

60. Find the volume of a solid which weighs 100 gms in vacuo and 50 gms. in water.

61. A hollow metal stopper weighs 30 gms. in air and in water it weighs only 5 gms. The density of the metal being 3 find the volume of the internal cavity.

Here, volume occupied by the metal (excluding the cavity)

$$=\tfrac{30}{3}=10 \text{ cc.}=\text{vol. of displaced water}$$
$$=\text{loss. of wt. of body in water}$$

Now, total volume $=(30-5)=25$ c.c.

Hence volume of cavity $=15$ c.c.

62. Weight of a body in air is 20 gms. and in water it weighs 15 gms. Find its apparent weight in a liquid of specific gravity 0.5.

63. Two bodies are in equilibrium when suspended in water from the arms of a balance : the mass of one is m_1 and its density is s_1. If the mass of the other is m_2. what is its density ?

Volume of the 1st. body $v_1=m_1/s_1$

" " 2nd " $v_2=m_2/s_2$ where $s_2=$ its density

App. wt. of the 1st body in water $=m_1-m_1/s_1$

" " " 2nd " " $=m_2-m_2/s_2$

and these are equal, being in equilibrium,

Hence, $m_1-m_1/s_1=m_2-m_2/s_2$

whence, s_2 is found.

64. Two masses of 28 gms and 36 gms respectively balance each other when weighed in water. The specific gravity of the first is 5.6. Find the specific gravity of the other ?

63. Two masses A and B are suspended from the two arms of a balance and are in eqnilibrium when B is immersed in alcohol (specific gravity .795) aud A in Nitric acid (specific gravity 1.50). If the specific gravities of A and B are 19.3 and 10.57 respectively, compare the masses of the two.

65. A piece of metal weighs 100 gms. in air, 70 gms. in water and 58 gms. in another liquid. Find the specific gravity of the liquid.

Loss in weight in water $= 100 - 70 = 30$ gms.

$=$ weight of water displaced in c.c.

Loss in weight in the liquid $= 100 - 58 = 42$ gms.

$=$ weight of liquid displaced.

$\therefore$ specific gravity of the liquid

$= 42/30 = 1.4.$

67. A body weighs 120 gms. in vacuo and 60 gms. in a liquid of specific gravity 1.5. Find the specific gravity of the body.

68. A body weighs 100 gms. in air 84 gms. in water and 78 gms. in another liquid. Find the specific gravity of the liquid.

69. Find the specific gravity of a given solid which is lighter than water from the following data :—

Weight in air $= 0{\cdot}2$ gms.

Weight of sinker in air $= 3.0$ gms.

Weight of solid + sinker in water $= 2.45$ gms.

Specific gravity of sinker $= 7{\cdot}0$ gms.

Here, Loss in weight due to sinker alone $= 3.0/7 = 0{\cdot}43$ gms.

Total loss in weight $= (3.2 \quad 2.45)$ gms. .. $= 0.75$ gms.

Loss in weight of the solid $= 0\ 75 - 0.43$ .. $= 0.32$ gms

$=$ weight of an equal volume of water.

$\therefore$ Specific gravity of the solid $= 0{\cdot}2/0.32 = {\cdot}625.$

70. Find the specific gravity of a piece of wood from the following data :—weight of wood $= 230$ gms., weight of a piece of iron in water $= 580$ gm. weight of the wood and iron together in water $= 465$ gms.

71. A piece of cork weighing 10 gms. and a sinker weighing 38 gms. just sink together when placed in water. The specific gravity of the sinker being 4.75 – find that of the other •

72. A Nicholson hydrometer required a weight of 8.35 gms. to be placed on the upper pan in order to make it sink to a fixed mark on the stem. The weights taken off when a piece of metal was placed in the upper pan were 5.81 gms; the weights added when the piece of metal was transferred to the lower pan were 2.92 gms. Find the specific gravity of the metal.

The weight of the metal is evidently $= 5.81$ gms.

Again the buoyancy of the metal is 2.92 gms

Hence, specific gravity $= \frac{5.81}{2.92} = 1.99$.

73. In an experiment with a solution of salt in water containing 30 gms of salt in 100 gms of the solution the weight of the hydrometer was 10 gms and the weight required to make it sink in water was 15 gms. The weight required to sink it in the salt solution was 17 gms. Find the specific gravity of the salt solution.

Here, weight of water displaced

$=$weight of the hydrometer

$+$weight on the hydrometer pan

$=(10+15)$ gms$=25$ gms.

Weight of salt solution displaced

$=27$ gms.

Hence, specific gravity of salt solution

$= \frac{27}{25} = 1.08$.

74. 100 gms has to be placed in the pan of a hydrometer to sink it to the mark in water and 50 gms only in another liquid. If the weight of the hydrometer is 100 gms—find the specific gravity of the liquid ?

75. A flask which when filled with water weighs altogether 410 grms, has 80 gms. of a solid introduced, and being then filled up with water weighs 470 gms. What is the volume of a kilogramme of the solid and also tho specific gravity of the solid ?

76. A nugget of gold mixed with quartz weighs 12 ounces and has a specific gravity 6.4; given that the specific gravity of gold is 19.35 and of quartz 2.15—find (to one place of decimal) the quantity of gold in the nugget.

Let x be the quantity of gold in the nugget

Then $12-x$ is „ quartz „ „

Then vol. of gold $= \frac{x}{19.35}$.

and „ „ quartz $= \frac{12-x}{2.15}$

Total vol. contained in the nugget $= x/19{\cdot}35 + (12 - x)/2{\cdot}15$

Its wt. is $\left(\frac{19{\cdot}35}{x} + \frac{12-x}{2{\cdot}15}\right)6{\cdot}4 = 12$ ozs.

Whence $x = 8{\cdot}9$ ozs.

77. A lump of metal is known to consist of silver and gold but it is not known how much gold and how much silver. The lump weighs 20 gms in air and 18.7 gms. in water. How much gold is there in the mixture ?

Specific gravity of gold = 19.3 of silver = 10.5.

78. A piece of lead weighs 7.88 gms. in air, 7.19 gms. in water and 7.33 gms. in alcohol. A piece of oak weighs 13.21 gms. in air and the oak and lead together weighs 4.87 gms. in water; find the specific gravity of lead, oak and alcohol.'

79. A body of specific gravity 1.85 is weighed in a mixture of alcohol, (specific gravity 0.82) and water. Its weight in air is 28.8 gms. and in the mixture 14.1 gms. Find the proportion of alcohol present ?

Weight of water displaced $= 28.8 / 1.85 = 15.57$ gms.

Weight of mixture displaced $= 28.8 - 14.1 = 14.7$ gms.

$\therefore$ Specific gravity of mixture $= 14.7/15.57 = .944$.

Now, Let V = total volume of mixture

V^1 = volume of alcohol present.

Then $V - V^1$ = volume of water present.

Hence $V \times .944 = (V - V^1) \times 1 + V^1 \times .82$.

Or $V \times .056 = V^1 \times .18 \therefore V^1 = .31\,V$.

$\therefore$ 0.31 of the volume is alcohol.

80. The volume of a balloon is 200 cubic metres and its weight with car is 12 kilograms. Determine the lifting power of the balloon when it is filled with coal gas 1 litre of which weighs 1·193 gm.—a litre of air weighing 1.293 gm.

Buoyancy per litre = 1.1.

Volume of balloon $= 200 \times 100 \times 100 \times 100$ cc.

in litres $= 200 \times 10 \times 100$

Buoyancy $= 200 \times 1000 \times 1{\cdot}1 = 220{,}000$.

Lifting Power $= 220{,}000 - 120{,}000 = 100{,}000 = 100$ kgm.

81. Find the lifting power of a balloon of 500 cubic metres capacity and filled with hydrogen. (1 litre of hydrogen weighs 0.089 gm. and 1 litre of air weighs 1.293 gm.)

82. Describe some form of air-pump. If the size of the receiver of an air-pump be 1 cub. ft. and that of the barrel of the pump 24 cub. in., how many strokes are required to reduce the pressure of the air to one-tenth the atmospheric pressure?

Let V=vol. of receiver$=12\times12\times12$ cub. in.

v=vol. of barrel$=24$ cub. in.

ρ = density of air before the operation.

ρ_1= „ „ after 1st. upstroke.

ρn= „ „ „ nth. „ .

Then after the 1st upstroke

$$V\rho=(V+v)\rho_1 \text{ whence } \rho_1=\frac{V}{V+v}.\rho.$$

After the nth upstroke $\rho n=\left(\frac{V}{V+v}\right)^n.\rho.$

By Boyle's Law, density varies as pressure

Hence $\rho n/\rho=1/10$.

Substituting for V and v, $\left[\frac{72}{73}\right]^n=\frac{1}{10}$

Or $\quad n\{\log 72-\log 73\}=-\log 10=-1$

Or $\quad n\{1{\cdot}857-1{\cdot}863\}=-n({\cdot}006)=-1$

whence $n=167$

83. The volume of the receiver of an air pump is 500 cc. and that of the barrel is 75 cc. Find after how many strokes the pressure will be reduced to less than half of its original value.

84. Explain how to compare the densities of two liquids which do not mix by means of a U-tube. Mercury is placed at the bottom of such a tube and water sufficient to occupy a length of 54 cms. of the tube is poured into one limb. By how much will the level of mercury be altered and how much oil must be poured into the other limb to bring it back to its original position?

85. The lower portion of a U-tube contains mercury. How many inches of water must be poured into one limb of the tube to raise the mercury 1 inch in the other, the specific gravity of mercury being 13·6?

CHAPTER III.

HEAT.

Thermometric Scales—The rule of conversion from one scale to another is given by

$$\frac{F-32}{9}=\frac{C}{5}=\frac{R}{4}.$$

1. Find the relation between the different scales of temperature.

2. Convert the following centigrade temperatures into their equivalent Fahrenheit

(i) 20°C (ii) 850°C (iii) −6°C (iv) −50°C (v) 18°C. (vi) 100°F.

3. Convert the following into their equivalent Centigrades.

(i) 230°F (ii) 27°F (iii) −10°F (iv) −49°F (v) 212°F (vi) 32°F.

4. The freezing point of mercury is given by the same numbers on the centigrade and the fahrenheit scales. Find the temp.

We have $\frac{F-32}{9}=\frac{C}{5}.$

Let x be the reqd. reading on both the thermometric scales

then $\frac{x-32}{9}=\frac{x}{5}.$ or $x=\frac{9}{5}x+32$

$$x=-40.$$

5. Convert the following Centigrade temperatures to their equivalent Fahrenheit and represent their relation by a graph.

(1) 10°c (2) 20°c (3) 30°c (4) 40°c (5) 50°c (6) 60°c (6) 60°c (7) 70°c (8) 80°c (9) 90°c (10) 100°c.

6. Find the temp. which is given by the same reading on both the Fahrenheit and the Reaumer scales.

Expansion of Solids—

Let l_0 be the length of a body at $0°C$

l^1 „ „ „ „ at $t°C$.

α the linear co-efficient of expansion of the substance of the body.

Then $\alpha = \dfrac{l^1 - l_0}{l_0 t}$ ... ... (1)

Hence $l^1 = l_0(1 + \alpha t)$ ... (2)

And increase in length $= l^1 - l_0 = l_0 \alpha t$ ... (3).

Similarly for surface and volume expansions we have,

Surface expansion $S = S_0\ (1 + \beta t)$

Volume „ $V = V_0\ (1 + \gamma t)$

where β = the co-eff. of superficial expansion $= 2\alpha$

and $\gamma =$ „ „ cubical „ $= 3\alpha$

7. The length of a copper rod at $0°C$ is 100 cms. Find its length at (1) $100°C$ (2) $150°C$ (3) $500°C$.

$l' = l_0\ (1 + \alpha t)$

Here $= 100\ (1 + .000017 \times 100)$

$= 100 \times 1.0017 = 100.17$ cms.

8. A bar of steel is 10 yds. long at $0°C$. What will be its length at $30°C$?

9. The length of an iron rod at $0°C$, is 100 cms. Find its length at $10°C$?

10. If an iron steam pipe is 60 ft. long at $0°C$. what is its length when steam passes through it at $100°C$.

11. A piece of iron wire is exactly 100·24 cms. at $200°C$. What will be itslength at $0°C$?

$l' = l_0\ (1 + \alpha t)$

Here $100.24 = l_0\ (1 + .000012 \times 200)$

$= l_0 \times 1.0024 \quad \therefore\ l_0 = 100$ cms.

12. A brass and a steel rod are each one metre long at 10°C. Find the difference in their length at 60° C.

13. A platinum wire and a brass wire each measures 300 cms at 100°C. Find their length at 0°C.

14. If a brass yard measure be correct at the temperature of melting ice, what will be its error at the temperature of boiling water?

$$\text{Increase in length} = l_0 \alpha t = 36 \times \cdot 000019 \times 100 = 0.0684.$$

15. An iron bar 2 ft. long at 0°C increases in length by a quarter of an inch, when placed in a furnace. What is the temperature of the furnace?

16. The length of a certain copper rod is 30 in. at 0°C. What is the length of a steel rod at 0°C that has the same length as the copper rod at 100°C?

17. The iron rails on a railway are 5 ft. long. What space must be left between two consecutive rails to allow space for expansion if the temperature may range over 100°C?

18. The length of a glass tube at 0°C is 153·86 cms. and at 100° it is 154 cms. Find the co-efficient of expansion for glass.

19. A copper rod is 100 cms. long at 0°C; at what temp. will it have increased by 1 mm?

20. Explain why the lengths of the metal bars of a compensated pendulum should be inversely proportional to the co-efficient of expansion of the metals.

21. A gridiron pendulum has 5 iron rods, each of 1 metre length and 4 brass rods. Find the length of each brass rod.

As the expansion of rods of the same material on either side of the central rod are the same, we have to consider here the expansion of *three* iron rods and *two* brass rods only.

$$\text{Hence } \frac{3l}{2l'} = \frac{\cdot 0000189}{\cdot 0000117} = \frac{189}{117}. \text{ whence to find } l'.$$

22. A gridiron pendulum contains 3 feet of iron rod. What length of zinc rod will be required to be used in its construction?

Expansion between any two temperatures;—

we have $l' = l_0 (1 + \alpha t)$.

and $l' = l_0 (1 + \alpha t)$

$$\therefore \qquad \frac{l'}{l}=\frac{(1+\alpha t')}{(1+\alpha t)}$$

$$\text{or} \qquad l'=l\ \frac{(1+\alpha t')}{(1+\alpha t)}$$

$$i.e. \qquad =l\,(1+\alpha t'-\alpha t+\ldots\ldots$$

$$=l(1+\alpha t'-\alpha t).$$

neglecting terms involving square and other powers of α, as α itself is very small.

$$\text{Hence} \qquad l'=l\,\{1+\alpha(t'-t)\}$$

23. The distance between two marks on a copper rod at 10°C is 200.34 in. Find the length at 100°C.

Here difference in temp. $=90^\circ$.

$\therefore$ Increase in length $=l\alpha(t'-t)$

$=200.34\times 90\times .000017=\cdot 306.$

$\therefore$ length at 100°C $=200.34+0.306=200.646$ in.

24. What change takes place in the diameter of an iron hoop which measures 80 cms across at 10°C, when the temperature changes to 30°C ?

25. A certain bridge of iron is 30 yds. long. Find its change in length during the year, assuming the range of temp. to be —15°C to 45°C.

26. Two bars of iron and copper differ in length by 10 cms. at 0°C. What must be the lengths of the rods in order that they may differ by the same amount at all temperatures ?

27. A certain clock with an iron pendulum rod is made to keep correct time at 5°C. How will its rate alter if the temp. rises to 30°C ?

There are $24\times 60\times 60$ or 86400 secs in a day

$\therefore$ A correct seconds pendulum will make 86,400 swings.

Now the period of oscillation of a pendulum is given by

$$t=2\pi\sqrt{\frac{l}{g}}\ ;\qquad t'=2\pi\sqrt{\frac{l'}{g'}}$$

$$\text{Here}\ \frac{t}{t'}=\sqrt{\frac{l}{l'}}=\sqrt{\frac{1}{1\cdot 0003}}$$

For $l' = l_0 (1 + .000012 \times 25)$.

$= l (1 + .0003)$.

$= l (1.0003)$.

Here if $t = 1$, $t' = \sqrt{1.0003}$

$\therefore$ No. of swings at 30°C $= \dfrac{86400}{\sqrt{1.0003}}$

$= 86400(1 + \cdot 0003)^{-\frac{1}{2}}$

$= 86400(1 - \cdot 00015)$ approx.

Hence the clock loses $86{,}400 \times .00015$ secs.

or 12·96 secs per day.

28. A pendulum consists of a bob suspended by a steel wire, whose co-efficient of expansion is $1 \cdot 24 \times 10^{-5}$. If the pendulum beats seconds at 0°C, find the number of seconds lost per day supposing that the temp. is constant throughout the day and equal to 25°C.

29. An iron clock pendulum makes 86,405 oscillations per day; at the end of the next day the clock has lost 10 seconds; find the change in temperature.

Times of oscillation in the two cases are

$$t = \frac{86400}{86405} \text{ sec and } t' = \frac{86400}{86395} \text{ sec.}$$

Since the clock loses, its former length say l has evidently increased due to a rise of temperature t to some length l' such that

$$l' = l (1 + \cdot 0000117\ t)$$

But $t'/t = \sqrt{l'/l}$

Or $\dfrac{86405}{86395} = \sqrt{1 + \cdot 0000117 t}$

Or $1 \cdot 0001157 = (1 + \cdot 0000117 t)^{\frac{1}{2}} = 1 \cdot 00000585 t + \cdots$

whence $t = 19^\circ.8$C.

30. The end of an iron boiler is a circle of 3 ft. in diameter at 0°C. What is the change in its area when heated to 100°C?

Area of circle $= \pi r^2 = \frac{22}{7} \times 1.5 \times 1.5$

Also $S_t = S_0(1 + \beta t)$

$= \frac{22}{7} \times 1.5 \times 1.5(1 + .000024 \times 100)$.

$\therefore$ Ch. in area $= S_t - S_0 = \frac{22}{7} \times 1.5 \times 1.5 \times .0024$

$= .017$ sq. ft.

31. A brass sheet is 10 cms long and 10 cms broad at 0°. Find its superficial area at 100°C.

32. The volume of a piece of glass at 100°c is 100.258 and its volume at 0°C is 100 cms. Find the co-efft. of cubical expansion of glass.

$$V_t = V_0 (1 + \gamma t)$$

$$100.258 = 100(1 + 100\gamma)$$

$$= 100 + 10000\gamma.$$

$$\therefore \quad \gamma = \frac{.258}{1000} = .0000258.$$

33. Linear expansion for glass is 0.0000083. Find the volume at 15°C of a glass flask of exactly 1 litre capacity at 0°C.

34. A glass vessel holds 6 litres at 15°c. How much will it hold at 25°C ?

35. A lump of iron has a volume of 10 cub ft. at 100°C Find its volume at 21°C. (α for iron $= .000012$)

$$V_t = V_0\{1 + \gamma (t' - t)\}.$$

$$10 = V_0(1 + .000036 \times 75).$$

$$= V_0(1 + .0027)$$

$$V_0 = \frac{10}{1.0027} = 9.97 \text{ cub. ft.}$$

36. α for a certain metal is 0.000017. How much must be the temperature raised in order that it may increase 1 per cent. in volume ?

37. The density of a piece of glass at 10°C is 2.6001 and at 60°C is 2.5967. Find the mean co-efficient of cubical expansion of glass.

Now we have

$$\rho = \rho_0 (1 - \gamma t)$$

Here t the diff. in temp. is 50°C.

$\therefore \quad 2.5967 = 2.6001(1 - 50\gamma)$

$= 2.6001 - 50\gamma \times 2.6001.$

Then $50\gamma = \frac{34}{26001}$ whence $\gamma = \cdot000026$.

38. The specific gravity of a metal at 0°C is 5. Find its value at 100°C referred to water at 0°C. (The co-efficient of linear expansion of the metal is 0.000016.)

Expansion of Liquids—

The relation between the co-efficient of absolute and the apparent expansion of a liquid is given by

$$\gamma = \gamma' + g, \text{ where}$$

γ = co-efficient of absolute expansion of liquid.

γ' = ... apparent ... ...

g = ... expansion of the containing vessel.

39. The co-efficient of absolute expansion of mercury being 1/5550 and its co-efficient of expansion relative to glass being 1/6480; find the co-efficient of expansion of glass.

40. A glass vessel holds when quite full at the temp. of melting ice 20 cub. in. How many ounces of boiling water will it hold? (γ for glass is $\cdot000026$.)

$$V^t = V^o\ (1 + \gamma t)$$

$$= 20\ (1 + \cdot000026 \times 100) = 20\cdot052 \text{ cub. in.}$$

Now wt. of 1 cub. ft. of water is 1000 ozs.

$\therefore$, 20·052 cub. in. „ $\frac{20\cdot052 \times 1000}{12 \times 12 \times 12} = 11\cdot6$ ozs.

41. A solid at 0°C, when immersed in water, displaces 500 cub. in; at 30°C it displaces 503 cub. in: Find its mean co-efficient of expansion between 0° and 30°C.

42. Mercury is placed in a graduated glass tube and occupies 100 divisions of the tube. Through how many degrees must the temp. be raised to cause the mercury to occupy 101 divisions?

Now γ for mercury $= \cdot00018$

g for glass $= \cdot0000254$.

$\therefore\ \gamma'$ ... $= (\gamma - g) = \cdot000154$

Again $V_t = V_o\ (1 + \gamma' t)$

$$101 = 100\ (1 + \cdot000154t.)$$

$$1 = 0\cdot0154\ t \quad \textit{Or} \quad t = 64°\cdot93\text{C}.$$

43. An iron bottle contains 20 lbs. of mercury at 0°C but at 100°C it only contains 19·72 lbs. α for iron being 0.000012, find γ for mercury.

Here the volume of the bottle as also that of mercury does not change while the density of mercury alone changes.

Then we have

$$V\rho = V\rho_0\,(1-\gamma' t)$$

Or $\qquad 19.72 = 20\,(1-100\gamma').$

Or $\qquad 2000\gamma' = 0.28$

Hence $\qquad \gamma' = 0.00014$

$\therefore \qquad \gamma = \gamma' + g = \cdot 00014 + \cdot 000036 = 0\cdot 000176.$

44. In an experiment, a piece of glass weighing 45 gms. in air was found to weigh 30 gms. in water at 4°C and 30·32 gms. in water at 60°C. Find γ for water, taking that of glass as ·000024.

Loss in wt. of glass in water at 4°C

$$= (45-30)\text{ gms} = 15\text{ gms.}$$

$\therefore$ Vol. of glass at 4°C $= 15$ *c.c.*

At 60°C this volume becomes

$$15\,(1+0\cdot 000024\times 56) = 15\times 1\cdot 001344$$
$$= 15\cdot 02016\text{ cc.}$$

Loss in wt. in water at 60°C

$$= (45-30\cdot 32)\text{ gms.} = 14\cdot 68\text{ gms.}$$

i.e. 14·68 gms. of water at 60°C occupies 15·02016 *c.c.*

$\therefore$ Density of water at 60°C

$$= 14\cdot 68/15\cdot 02016$$

which again $\qquad = 1-56\,\gamma$

or $\qquad \gamma = \cdot 00041$ app.

45. The co-efficient of cubical expansion of mercury is ·000180 and of brass ·000060 per 1°C. Find the atmospheric pressure in inches of mercury at 0°C. when a barometer with a brass scale (correct at 62°*F.*) reads 30 in. at a temp. of 50°*F.*

$62^\circ F = 16^\circ {}^2/_3\, C$ and $50^\circ F = 10^\circ C$

Since the brass scale is correct at $16^\circ {}^2/_3$ c, its true height at 10°C

$=(1-\text{·}00002\times{}^{20}/_{3})$ where.

$20/3=$ Diff. in temp $=16^{2}/_{3}-10$.

$\text{·}00002=$ Lin. co-efft. for brass $=\text{·}00006/3$

$=29\text{·}996$ in. $=$ true reading at 10°C.

Again the height of mercury at 0°C that occupies a length of 29·996 at 10°C. is

$$29\text{·}996=h_0'\,(1+\text{·}00018\times 10).$$

whence $h_0=29\text{·}942$ in.

and this is the required atmospheric pressure at 0°C.

46. A glass flask which holds 100 gms of a given liquid at 20°C holds 98 gms of the same liquid at 100°C. Find the co-efficient of expansion of the liquid neglecting that of the glass.

47. A weight thermometer contains 176·7 gms of mercury at 15°C and only 174·4 at 100°C. calculate the apparent expansion of mercury.

49. The apparent co-efficient of expansion for mercury in glass is ·000154. Find the mass of mercury that overflows from a weight thermometer containing 360 gms. of mercury. at 0°C when the temp. rises to 98°C.

50. The density of water at 60°C is 0·98 : find the co efficient of expansion of water between 4°C and 60°C if the density at the former temperature be unity.

51. A mass of mercury occupies 8·0144 cub. inches at 10°C. Find the temperature at which the volume is increased by 0·0432 cubic inches.

52. In an experiment with Dulong and Petit's apparatus of measuring the real expansion of mercury the hot column was kept at 100°C and the cold column at 0°C. The height of the hot column was 50·9 cms. and that of the cold column was 50 cms. Find the co-efficient of expansion of mercury.

Here $=\dfrac{50\text{·}9-50}{50\times 100}=\dfrac{\text{·}9}{5000}=\text{·}00018$

Expansion of Gases :—

According to Charles' Law

$V = V_0(1+\gamma t)$ where

V_0=vol. of any gas at 0°C

V= " " " " t°C

γ=co-efft. of expansion of gas

= 1/273 app.

Hence increase in volume= $V_0\gamma t$

52. A certain quantity of gas measures 100 *cc.* at 0°C; Find its volume at (i) 100°C (ii) 150°C (iii) 300°C.

$$V_{100} = V_0\left(1+\frac{100}{273}\right)$$
$$=100\left(1+\frac{100}{273}\right)=137\ cc.$$

53. A litre of hydrogen, at 10°C is heated at constant pressure to 283°C. Find its volume.

54. A certain quantity of gas occupies a volume of 28 litres at 21°C. Find the volume at 0°*c*.

55. A litre flask contains 0·9487 gms of air at 100°C. How much will it contain at 0°C.

56. Find the change of volume produced by heating 91 *c.c.* of a gas from 0°C to 24°C.

Change in Vol.$=V_0\gamma t=91\times\frac{1}{273}\times 24=8$ *c.c.*

58. To what temp. must a gas be heated in order that its volume may become double of what it is at 0°C.

Here $V_t = V_0(1+\gamma t) = 2V_0$

59 A quantity of air measures 285 *c.c.* at 77·6°C, Find the temp. when its volume will be 230 *c.c* .

60. The volume of a certain quantity of air at 10°C is 130 *c.c.* and the volume at 31°*c* is 140 *c.c.* Find γ.

$V = V_0(1+\gamma t)$

Here $140=130(1+21\gamma)=130+21\times 130\gamma$.

$$\gamma=\frac{10}{21\times 130}=\frac{1}{273}.$$

61. 1 gm. of Hydrogen occupies 11·16 litres at 0°C and at 30°C it occupies 12·39 litres under the same pressure. Find γ

Charles' Law in Absolute Temperature—

$$V=V_0(1+\gamma t) \qquad \text{where } V-\text{vol. at } t^\circ\text{C}$$
$$V'=V_0(1+\gamma t') \qquad ,, \quad V'-\text{vol. at } t'^\circ\text{C}$$
$$\therefore \quad \frac{V'}{V}=\frac{1+\gamma t'}{1+\gamma t}$$
$$=\frac{1+t'/273}{1+t/273}=\frac{273+t'}{273+t}=\frac{T'}{T}.$$

where T and T' are temperatures measured on the abs olute scale.

Thus we have

$$\frac{V}{T}=\frac{V'}{T'}$$

61. 1000 *cc.* of air weigh 1·293 gm. at 0°C. and 0·9487 at 100°C. Calculate γ for air from these data.

$$V=\frac{M}{\rho}=\frac{M'}{\rho'}$$
$$\therefore \quad \frac{M'}{M}=\frac{\rho'}{\rho}=(1-\gamma t) \qquad \text{for } \rho'=\rho(1-\gamma t).$$

Then we have $\dfrac{0·9487}{1·293}=(1-100\gamma)$, whence $\gamma=0·0036$.

62. Supposing that a quantity of gas were to occupy 500 *c.c.* at 80°C and 600 *c.c.* at 120°C what would be the mean γ for the gas between 80° and 120°C.

63. Find the density of air in a furnace whose temp. is 1200°C; the density of air at 0°C is 0·001293.

64. 300 *c.c.* of air is measured at 27°C. what will be the volume at 40°C, the pressure remaining constant?

$$\frac{\text{Vol. at } 40^\circ\text{C}}{300}=\frac{273+40}{273+27}=\frac{313}{300}=313 \ c.c.$$

65. 12·38 litres of air weigh 1 gm at 30°C. Find its volume at 50°C.

66. A quantity of gas measured at 0°c. and 760 mm. has a volume of 354 c.c. Find the volume at 27°c and 740 mm.

We have $\frac{PV}{T}=\frac{P'V'}{T'}$

i.e. $\frac{354\times760}{273}=\frac{740\times V}{300}=400$ *c.c.* app.

67. A quantity of air occupies a volume 0.8026 litre at 100°c and 609 mm. pressure. Find its volume.

(i) at N. T. P.
(ii) 100°C and 752 mm.
(iii) −50°C and 760 mm.

68. A quantity of gas occupies 580 c.c. at 17°C and 780 m.m. pressure. What would be the volume at (*a*) 30° if the pressure remains constant, (*b*) at 30° and 760 m.m ?

69. The temp. of a quantity of air collected at N. T. P. is increased to 7°.18 C. To what the pressure must be changed in order that the volume may regain its original value ?

70. A gramme of gas at 27°C has the pressure on it halved and is then cooled until it occupies the same volume as the first. What is its final temperature ?

71. A mass of air under a given pressure occupies 44 cub. in. at a temp. of 13°C. If the volume of the air be reduced to 24 cub. in. and the temp. raised to 39°C. show that the pressure will be doubled.

72. A cubic foot of dry air weighs 540 gr. at 14°C and 30 in. pressure. Show that an equal vol. of air will weigh about 535 gm. at 7°C and 29 in. pressure.

73. A quantity of gas is collected in a graduated tube over mercury. The volume of the gas at 10°c is 50 c.c. and the level of mercury in the tube is 10 cms. above the level outside; the barometer stands at 75 cm. Find the volume which the gas would occupy at 0°C and 76 cm. barometric pressure.

$\frac{PV}{T}\quad\frac{P'V}{T}$

Here, $P=(75-10)=65$ cms,

Also, $V=10$ and $T=(273+10)=283$.

$P'=76$ and $T'=273$.

Or $$\frac{65 \times 50}{283} = \frac{76 \times V'}{273}$$

Or $$V' = \frac{443625}{10754}$$
$$= 41 \cdot 25 \ c.c.$$

74. Determine the height of the barometer when a milligram of air at 27°c occupies a volume of 20 c.c. in a tube over mercury, the mercury standiug 73 cms. higher inside the tube than outside.

75. 3 c.c. of air at atmospheric pressure is introduced into the space above the mercury in a barometer reading 760 m.m. originally. The volume of air measures 4 c.c. Find the depression of the mercury column.

76. At 16°C and 30.6 in. pressure a quantity of gas occupies 153 cub. in. find its voume at 2°c and 29·7 in.

77. A quantity of gas occupies 40 cub, in. at a pressure of 30 inches and temp. 32°C. Find the pressure if the volume is altered to 38 cub. in. and the temp. to 5°C.

Specific Heat :—

78. 100 gms of water at 50°C is mixed with 10 gms of water 0°C. Find the resulting temperature.

79. A body of 10 gms is heated to 100°C and is then dropped into 40 gms of water at 10°0. Find the resulting temperature, the specific heat of the body being 0.01.

Let t be the resulting temp.

Then, Heat *lost* by the body in falling from 100°C to t°C

= Heat *absorbed* by water in rising from 10°c to t°C.

Or $10 \times .01(100 - t) = 40(t - 10)$

$t = 9°.8C.$

80. Calculate the amount of heat required to raise 50 gms. of a metal from a temp: of 30° to 100°0 and find the resulting temp. if the metal is then dropped into 10 gms of water at 20°C. The specific heat of the metal is 0·1.

81. A body of mass 10 gms at 100°C is dropped into 10 gms of water at 45°C and the resulting temp. is 50°C. Find the specific heat.

82. 2500 gms of a substance at 95° when put in 3000 c.c. of water at 15°C produce a rise of temp. of 6°.8C. Find the specific heat.

Water-equivalent :—

Water equivalent of a body = its mass × specific heat = ms.

83. Into a calorimeter whose temp. is 15°C is placed 34 gms. of water at a temp. of 50°C. The temp. of the two becomes 20°C. What is the water equivalent of the calorimeter.

Let w be the water-equivalent of the calorimeter.

Here mass of water = 34 gms.

Initial temp. of calometer = 15°C.

Temp. of hot water = 50°C.

Final temp. of water and cal. = 20°C.

Now, Heat lost by water = Heat gained by calorimeter.

Or mass of water × its fall of temp.

$= w \times$ rise of temp. of cal.

i.e. $34\,(50-20) = w(20-15)$

Whence $w = 204$ gms,

84. What do you mean by (1) a unit of heat (2 specific heat of copper = .092 (3) Latent Heat of steam = 536 ?

85. A copper calorimeter of specific heat 0.095 has a mass of 120 gms. and contains 280 gms. of water at 15°C. Find the specific heat of a substance when 375 gms of it at a temp. of 100°C when immersed raises the temp. of the water to 25°C.

86. The weight of a copper calorimeter is 110 gms. and the specific heat of copper is 0.095. 400 gms. of water at a temp. of 16°C are put into the calorimeter and 60 gms. of a substance which has been heated to 98°C. Find the specific heat of the substance, the resulting temp. being 21°C.

Let S be the specific heat. Then

(i) Heat lost by the substance $= 60 \times (98-21) \times S$ calories.

(ii) Heat absorbed

(*a*) by water $= 400(21-16)$ calories.

(*b*) by calorimeter $= 110 \times \cdot 095(21-16)$ calories.

Hence $60 \times 77 \times S = 5 \times (400 + 10 \cdot 45)$ calories.

$\therefore\ 924\,S = 410 \cdot 45$

$S = \cdot 444.$

87. A ball of copper weighing 1·718 gm at 98°C is put into a copper vessel containing 2 lbs. of water at 15°C and the temp. of the vessel after the experiment is 21°C.; the weight of the vessel being 1 lb., find the specific heat of copper.

88. In order to determine the specific heat of silver a piece of the metal weighing 21 gms, is heated to 98°C and then dropped into a calorimeter containing 100 gms. of water at 10°C. The final temp. of the mixture is 11°C. Find the specific heat of the silver, the water equivalent of the calorimeter etc. being 3·6.

89. Determine the specific heat of copper from the following data—

Weight of copper	= 16·65 gms.
Weight of water in calorimeter	= 49 gms.
Initial temp. of copper	= 99.°5C
„ „ water in calorimeter	= 12.°0C
Final „ of mixture	= 14.°5C.
Water equivalent of calorimeter, etc	= 2·1 gms.

90. Determine the specific heat of alcohol from the following data: -

Weight of copper calorimeter ..	= 20·48 gms.
„ „ „ + alcohol ..	= 70·5 „
„ „ dropped in calorimeter	= 10·5 gms.
Initial temp. of cal. + alcohol ..	= 10°C.
„ „ copper ...	= 98·0°C.
Final „ mixture ...	= 12·6°C

91. A quantity of turpentine 250 gms in weight, is enclosed in a copper vessel whose mass is 25 gms. and is heated to 100°C. On immersing the whole in 535 gms. of water at 13°C in a copper calorimeter 110 gms. in mass the temp. rises to 27.5°C. Assuming the specific heat of copper to be 0·1, find that of turpentine.

92. A mass of 200 gms. of platinum at 90°C is placed in 100 gms. of turpentine within a copper calorimeter whose mass is 30 gms. and temp. 15°C. The final temp. of the whole is 21·7°C. Find the specific heat of the liquid if that of the copper be 0·96 and platinum ·032.

93. A mass of 200 gms. of copper whose specific heat is 0·095 is heated to 100°C and placed in 100 gms. of alcohol at 8°C contained in a copper calorimeter whose mass is 25 gms. and the temp. rises to 28·5°C. Find the specific heat of alcohol.

(1) Heat given out is that from 200 gms. of copper when its temp. falls from 100°C to 28°·5C.

$$=200\times.095\times(100-28.5)$$
$$=19\times71.5$$
$$=1358.5 \text{ calories}.................(1).$$

(2) Heat absorbed is divided into two parts ;—

(*a*) that absorbed by calorimeter weighing 25 gms. when the temp. rises from 8°C to 28°.5°C.

$$=25\times.095\times20.5=48.7 \text{ calories......}(a)$$

(*b*) that absorbed by 100 gms. of alcohol of specific heat S when the temp. rises from 8°C to 28.5°C

$$=100\times8\times20.5=2050\,S...........(b)$$

Now $(1)=(a)+(b)$.

$\therefore\ 1358.5=48.7+2050\,S.$

$2050\,S=1309.8$ whence $S=0·639.$

94. If the heat evolved by 1 kg. of water in cooling down from 100°C, to 0°C were employed in heating 10 kg. of mercury initially at 20°C. to what temp. would the mercury be raised? (Specific heat of mercury = ·033)

95. A piece of platinum weighing 10 gms. is taken from a furnace and plunged instantly into 40 gms. of water at 10°C The temperature of the water rises to 24°C. What was the temperature of the furnace? (Specific heat of platinum = ·032.)

96. A ball of lead at 28°C is put into an iron vessel containing 2 lbs. of water at 15°C and the temp. of the water ball and vessel after the experiment is 21°C, the weight of the vessel being 1 lb Find the weight of the ball. (Specific heat of lead = ·0384 ; of iron = ·114).

97. Assuming that the density of boiling water is 0·96 and the density of mercury at 0°C is 13·6. Calculate the resulting temp. when equal volumes of boiling water and mercury at 0°C is mixed.

98. *A body heated to 100°C and dropped into 10 lbs. of water at 0°C raises the temp. of the water by 5°C. What effect would it have produced, had there been 15 lbs. of water at 30°C?

Change of State and Latent Heat :—

99. 100 gms. of ice at 0°C are converted into water at 0°C. What is the amount of heat absorbed?

1 gm. of ice in melting requires 79·5 units of heat.

$\therefore$ 100 gms. require $79·5 \times 100 = 7950$ units.

100. 40 gms. of water are converted in ice. What is the amount of heat given out ?

101. What amount of heat will be given out by 20 gms. of boiling water when it converted into ice at 0°C.

102. How much mercury as 20°C would be required to melt 1 kg. of ice at 0°C the specific heat of mercury being 0·033 ? (Latent heat of ice = 79·5)

Let m be the weight in kilogrammes of mercury reqd.

$\therefore$ Heat lost by mercury = Heat gained by ice.

i.e. $m\,(20-0) \times 0\,033 = 79·5 \times 1$, whence $m = 120·5$ kg.

103. How much ice at 0°C will be melted by 100 gms. of boiling water ?

104. How much boiling water at 100°C will just melt 625 gms, of ice ?

105. How much ice at 0°C would a kgm. of steam at 100°C melt if the resulting water was at 0°C.

106. 1 kg. of ice at 0°C is placed in 5 kg. of water at 0° and 1 kg. of steam at 100°C is passed into it. What will be the temp. of water, if no heat is lost by conduction or radiation ?

Let θ be the final temp. of the mixture.

(i) Heat given out by 1 kg. of water at 100°C in condensing to water at $100° = 537 \times 1000$ units.

(ii) Heat given out by water at 100° in falling from 100° to $0°C = 1000\,(100-\theta)$.

(iii) Heat absorbed by 1 kg. of ice at 0° to melt into water at $0°C. = 79.5 \times 1000$ units.

(iv) Heat absorbed by 6 kg. of water at 0°C in rising from 0° to $\theta°C = 6 \times 1000(\theta - 0)$.

As heat given out = heat absorbed, we have

$$1000 \times 537 + (100-\theta) \times 1000 = 79.5 + 6\theta) \times 1000$$

Then $7\,\theta = 557·5$ or $\theta = 79.°6$ C

107. A mass of iron weighing 400 lbs. and whose temp. is 440°C and specific heat ·114 is placed in a mixture of ice and water. How much ice wiil be melted, if the latent heat of ice is 79·5 ?

108. How many units of heat would cause a mixture of ce and water to contract by 50 cc., if 100 c.c., of water at 0°C becomes 109 cc. on freezing?

100 *c.c.* of water becomes 109 *c.c.* on freezing.

∴ in this occurs a change of 9 *c.c.*

Again 100 *c.c.* of water gives up

$$100 \times 79{\cdot}5 = 7950 \text{ units of heat.}$$

i.e. for a contraction of 9 *c.c.* 7950 units are given out.

∴ Heat given out on a contraction of 50 cc.

$$= \frac{50 \times 7950}{9} = 44166{\cdot}6 \text{ units.}$$

109. A mixture of ice and water is reduced in volume by 1 a cubic millimetre. What weight of ice has been melted?

110. The specific gravity of ice is 0·917. 10 gms. of a metal at 100°C are immersed in a mixture of ice and water, and the volume of the mixture is found to be reduced by ·125 cc. without change of temp. Find the specific heat of the metal.

Let S be the specific heat required.

(1) Heat given out by the metal $= 10 \times 100 \times S$

$= 1000\ S$ calories

(ii) Now vol. of 1 gm. of ice at 0°C $= 1/0{\cdot}917$

$= 1{\cdot}0905$ cc.

And vol. of 1 gm. of water at 0°C $= 1$ cc.

∴ Reduction of vol. when 1 gm. of ice is converted into 1 gm. of water at 0°C $= 0{\cdot}0905$ cc.

Hence mass of ice to undergo a contraction of 0·125 cc.

$$= \frac{\cdot 125}{\cdot 0905} = \frac{125}{90{\cdot}5} \text{ gms.}$$

∴ Heat absorbed by 125/90·5 gms. of ice

$$= \frac{125}{90{\cdot}5} \times 79{\cdot}5$$

And Heat absorbed = Heat gained

$$\therefore \quad \frac{125}{90{\cdot}5} \times 79{\cdot}5 = 1000\, S, \quad \text{whence} \quad S = 0{\cdot}197.$$

111. A gramme of ice at 0°C contracts 0·091 cc. in becoming water at 0°C. A piece of metal weighing 10 gms. is heated to

50°C and then dropped into the calorimeter. The total contraction is 0·063 cc. Find the specific heat of the metal, taking the latent of ice as 80.

112 Determine the Latent Heat of ice from the following data—

Weight of brass calorimeter (sp. heat 0.01) —30 gms.
" " " +water —1127 gms.
Initial temp. of water and cal. ... —24°C.
Final " " " ... —14°C.
Weight of calorimeter etc. after addition of ice
—1137 gms.

113. Determine the Latent heat of ice from the following data :—

Water equivalent of calorimeter (specific heat 0.1)
—3.
Weight of calorimeter + water —533 gms.
Initial temp. of water and cal. —50°C.
Final temp. of " " —20°C.
Weight of calorimeter etc after addition of ice —543 gms.

114. Find the result of mixing

(i) 10 gms. of water at 40°C with 1 gm of ice at 0°C.
(ii) 2 gms of ice at 0°C with 5 gms of water at 20°C.

Examples of this kind should be put to a preliminary examination in order to ascertain whether the whole of the ice or only a part of it will be melted. This may be ascertained from the following considerations:—

(i) In example (1) above, the number of units of heat required to melt 1 gm. of ice = 80.

Now 10 gms of water evolve in cooling from 40°C to 0°C
$= 40 \times 10 = 400$ units of heat

Since $400 > 80$, it is evident that the whole of the ice will be melted. Then the ice will take up only 80 units of heat out of the water and the resulting temp. will be higher than 0°. Let this temp. be t°C.

Then (i) Heat given out by water. $=100\times(40-t)$.

and (ii) Heat absorbed by ice at 0°

(a) in melting into water at $0°=80\times1=80$ units

(b) In rising from 0° to t°C $=t$ units

But Heat given out $=$ Heat absorbed

i.e. $10\times(40-t)=80+t$

Or $t=34°C$

∴ the result is 11 gms of water at 29°.C.

(ii) In this case only a portion of ice will be melted, since 5 gms. of water at 20°C in falling to 0°C evolves 100 units of heat and 2 gms. of water at 0°C in being converted to water at 0°C require $2\times80=160$ units of heat only.

Here $100<160$. ∴ only a part of ice will melt, the temp. of the mixture being 0°C.

If q denotes the quantity of ice melted.

We have $5\times20=80\times q$.

whence $q=1\cdot25$ gms.

115. What will be the result of placing (a) 5 lbs of copper at 100°C (b) 30 lbs. of copper at 8°C in contact with 1.5 lb. of ice at 0°C. (Specific heat of copper $=0.1$).

116. 1 lb. of ice at 0°C is put into 10 lbs. of water at 26.5°C. What is the final temp?

117. 10 gms of snow at -10°C are mixed with 120 gms. of water at 80°C. Find the final temp. of the mixture.

Latent Heat of Steam :—

118. Find the Latent heat of steam from the following data—

Weight of calorimeter (sp. heat .092)		—80 gms.
Wt. ,, ,, ,, and water	...	—180 gms.
Initial temp. ...	...	—10°C.
Final temp. ...	...	—80°C.
Weight of water + calorimeter after the experiment		—193.42 gms
Temp. of steam		—100°C

From the above we have—

Water equivalent of calorimeter $=80\times.09=7.2$.
Wt. of water in calorimeter $=100$ gms.
Wt. of steam condensed $=13\cdot42$ gms.

Now Heat giveu out by the steam = Heat gained by water

Or $13\cdot42\times L+13.42\,(100-80)$

$=(100+72)\times70$

$=7504$.

$13\cdot42\,L=7235.6\quad\therefore\quad L=540$ units

119. A calorimeter whose water-equivalent is 48 gms, has 352 c.c. of water in it and the whole weighs 882 gms. Into this steam at atmospheric pressure is condensed till the temp. rises from $12^\circ.2$ to $18^\circ.7$C and on weighing again the calorimeter weighs 886.2 gms. Calculate the latent heat of vaporisation of water.

120. It is found that one pound of steam at 100°C when passed into 15 lbs. of water at 0°C raise the temp. of the water to 40°C. From these data calculate the latent heat of steam.

121. A mass of 200 gms of copper (sp. heat $0\cdot1$) is hung in a closed chamber at a temp. of $15^\circ.5$C. Steam is then admitted at the normal atmospheric pressure. Calculate the mass of water condensed by the copper, the latent heat of steam being 536.

Heat taken up by the copper in rising from $15^\circ.5$C to 100°C (the temp. of the steam)

$=200\times\cdot1\times(100-15.5)$

$=1690$ units.

This heat is given out by x gms of steam in being condensed to x gms of water at 100°.C

$\therefore\quad 536\,x=1690$ units.

Or $\quad x=3\cdot15$ gms

122. Steam at 100°C is passed into a copper calorimeter weighing 100 gms. and containing 500 gms. of water at 15°C until the temp. of the calorimeter and its contents rises to 25°C. Calculate the weight of steam condensed. Given the specific heat of copper $=0.1$ and latent heat of steam $=536$.

123. 15 gms. of steam are blown into 80 gms. ice-cold water at 0°C. Find the rise of temp. produced. The water equivalent of the calorimeter is 15 gms; latent heat of steam is 536.

124. If 25 gms of steam at 100°C be passed into 300 gms of ice-cold water what will be the temp. of the mixture? The latent of heat of steam is 536.

125. A vessel containing 10 gms. of ice is held over a flame. How much heat will be required to melt the ice and vapourise it completely? Latent heat of ice=80; of Steam=536.

Vapour Pressure—

126. 100 c.c. of oxygen saturated with water are collected at a pressure of 740 mm. and a temp. of 15°C Find the volume of dry oxygen at 0°C and 760 mm. having given that the maximum pressure of aqueous vapour at 15°C is 12·7 mm.

Now pressure of the mixture

=pressure of oxygen+pressure of aqueous vapour.

∴ Pressure of oxygen=740—12·7=727·3

Volume of oxygen =100 cc.

Temperature „ =15°C=288 absolute

Apply $\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}$

Substituting, $\frac{727 \cdot 3 \times 100}{288}=\frac{760 \times V_2}{273}$

whence $V_2=\frac{727 \cdot 3 \times 100 \times 273}{288 \times 760}$

=90·7 c.c.

127. The boiling point of water at the sea level is 100°C and at a higher level is 90°C, the temperature of observation at the two places being 11°C and 5°C, respectively. Find the difference in level. (The density of dry air at 0°C and 760 *m.m.* is ·001293)

From the table, knowing the boiling point we can get the atmospheric pressure at the two places and these are here 760 *m.m.* 525 *m.m.* respectively. Then the mean pressure

$=(760+525)\frac{1}{2}=642 \cdot 5$

and the difference of pressure is=(760—525)

=235 *m.m.*

=23.5 cms.

The mean temp. is 8°C.

Again, a column of mercury 1 sq. cm. cross section and 23·5 cm. high weighs $13.6 \times 23{\cdot}5$ gms $= 319.6$ and this is the mass of a column of air 1 sq. cm. in area between the two stations. Again, the density of air at the mean pressure and temp. *i.e.* at 642·5 *m.m.* and 8°C.

$$= \frac{.001293 \times 642.5 \times 273}{760 \times 281} = .00106 \text{ gms.}$$

Hence, the difference in level

$$= \frac{\text{mass of the air column}}{\text{average density}}$$

$$= \frac{319.6}{.00106} = 3015.09 \text{ metres.}$$

128. 1 litre of dry Hydrogen at 0°C and 760 m,m. weighs 0.08936 gm. Find the weight of 1 litre of Hydrogen collected over watrer at 20°C (Vapour Pressure at 20°C = 17.39).

129. Calculate the hygrometric state of air from the following data :—

Actual temp.	—14°.5C.
Temp. at which dew appears	—9°.2c.
Vapour Tension of water at 5°c	—.0087 mm.
" " " " 10°C	—.0122 "
" " " " 15°C	—.0169 "

Mechanical Equivalent of Heat—

From the principle of conservation of energy we know that the various forms of energy may, though not always at will, be transformed one into another.

Thus when work is transformed into heat,—the quantity of heat produced is equivalent to the amount of work expended in its production, and conversely, when heat is transformed into work, the amount of work produced is equivalent to the quantity of heat expended in its prodnctions; but work is expressed in ergs and heat in calories; hence in order to transform one system into the other we multiply the quantity

of heat by a constant J, which is called the Mechanical equivalent and is equivalent to the work done in producing unit quantity of heat. Thus in all cases we have

$$W = JH$$

130. From what height must a block of lead fall in order to have its temperature raised through 10°C. (Specific heat of lead $= \cdot 03$).

131. A tube of length l cms is closed by two tightly fitting corks; m gms of small lead shot at t°C are poured into the tube —the tube being closed and held vertical—it is then inverted so that the shots fall along the whole length of the tube. This operation is repeated n times. Then the shot being removed from the tube, the temp. of the former (*i.e.* ol the shot) is noted and is found to be t'°C. Determine J.

Here m = weight of lead shot in grammes
l = distance in cms. the shot falls each time
n = number of times the the tube is inverted
$(t'-t)$ = rise of temperature in centigrade degrees.
s = specific heat of lead.

The work done by gravity

$= n \times m \times l$ gm. cms. units.

Heat gained by lead $= m \times s \times (t' - t$ calories.

$$\therefore \quad J = \frac{nml}{ms(t'-t)} = \frac{nh}{s(t'-t)}.$$

132. Calculate J from the following :—

Weight of lead	—434gms.
Specific heat of lead	—0.0315
Vertical height of fall	—67.7 cms.
Rise in temperture	—2°C.
Number of inversions	—40.

CHAPTER IV.

LIGHT.

In all cases of working out examples on Light students are advised to draw neat diagrams with black lead pencils.

Shadows ;—

1. A man $5\frac{1}{2}$ ft. high is standing at a distance of 10 ft. from a street lamp 11 ft. high. Find the length of the man's shadow upon the ground.

2. The diameter of a circular uniform source of light is 3 inches and it is placed at a distance of 20 ft. from a sphere of 3 inches diameter. Find approximately the diameter of the umbra and penumbra cast on a screen 10 ft. beyond the sphere.

Draw a figure first.

Diameter of source of light	= 3 in
„ „ sphere	= 3 in
∴ Diameter of umbra	= 3 in
Internal diameter of penumbra	= 3 in
External „ „ „	= 6 in. from similar triangles.

3. Outside a small hole in the wall of a dark room 10 ft. square is a tree 15 ft. high and distant 56 ft from the wall. The image of the tree falls on the wall of the room. Determine the height of this image.

Velocity of Light :—

4. Light takes $16\frac{1}{2}$ minutes to travel across the earth's orbit, the diameter of which is 296,000,000 kilometres or 184,000,000 miles. Calculate the velocity of light.

5. The diameter of the earth is 8000 miles and that of the sun is 860,000 miles. The earth is 93,000,000 miles from the sun. What is the length of the earth's umbra ?

6. If it takes 20 years for light to come from the star Sirius to the Earth, how far away is the star ?

Distance reqd. = 20 years in sec., $\times$ vel. of light.

7. If the star Arcturus, distant 600,000,000,000,000 miles from the earth were to explode suddenly how long would it be before astronomers could detect the fact?

Photometry ;—

The intensity of illumination at a point illuminated by a source of illuminating power I, at a distance r from it, is given by $P = I/r^2$.

As I is constant for the same source of light, $P \propto 1/r^2$. This is known as the *Law of Inverse Squares.*

Again if another source of light of illuminating power I' is placed at a distance r' from the same point so as to produce an equal illumination at the point, we have

$$P = I/r'^2$$

$$\text{Or} \quad \frac{I}{r^2} = \frac{I'}{r'^2}$$

$$\text{Or} \quad \frac{I}{I'} = \frac{r^2}{r'^2}$$

This is the law of *Direct Squares* or the Principle of Photometry.

8. Two sources of light of candle powers 2 and 6 respectively are placed at distances 4 and 10 cms on either side of a cardboard screen. Compare the illumination on the two sides of the screen.

$$\text{Illumination due to the first} = \frac{I}{r^2} = \frac{2}{4^2} = \frac{1}{8}$$

$$\text{,,} \quad \text{,,} \quad \text{,, second} = \frac{I'}{r'^2} = \frac{6}{100} = \frac{3}{50}$$

$\therefore$ Their ratio $\frac{1}{8} : \frac{3}{50} = 25 : 12$.

9. Compare the intensity of illuminaion at a place due to (i) a gas lamp of 500 C.P. placed 10 ft. high and (ii) an arc lamp of 1200 C.P. placed 60 ft. high.

10. A standard candle and a gas flame of 9 candle power are placed 20 cms. apart. Find where must a screen be placed between them so that the latter may be equally illuminated by each.

Let x be the reqd. distance as measured from the standard candle. Then its distance from the gas flame is $(20-x)$ cms. Then for equal illumination on the screen due to each we must have

$$\frac{1}{x^2}=\frac{9}{(20-x)^2}$$

$$20-x=\pm 3x$$

$$x=+5 \text{ or } -10.$$

i.e. Corresponding to the two values of x there are two positions where the screen may be placed; one of these is 5 cms to the right of the standard candle *i.e.* between the candle and the gas flame, while the second is -10 cm. to the left of the candle.

11. Two lamps of 8 and 32 c.p. are fixed 120 cms. apart. Where on the line joining them must a screen be placed so as to be equally illuminated by each ?

12. A gas flame of 16 c.p. and a lamp of 9 c.p. are placed 140 cms. apart. At what distance must a ~~gas flame of 16 c.p.~~ be placed so as to ~~produce an~~ equal illumination ~~of the surface ?~~

13. A 10 c.p. lamp is placed 1 metre from a surface. At what distance must a gas flame of 16 c.p. be placed so as to produce an equal illumination of the surface ?

14. Two sources of light A and B placed 100 cms. apart lie on either side of the screen of a photometer, A having 4 times the power of B. Find the position of the screen so that its sides shall be equally illuminated.

15. In the above example, if a semi-transparent sheet which cuts off 5/9 ths. of the light falling upon it be placed immediately in front of the source B, in what direction and how far must the photometer screen be moved in order that its sides may be equally illuminated.

Let the photometer screen be moved to a distance d from the source B

Then its distance from A is $100-d$.

Again $A=4B$ and since the semi-transparent sheet cuts off 5/9 ths. of the light from B, only 4/9 ths. of its illumination passes through. Hence we have

$$\frac{4B}{(100-d)^2}=\frac{4/9B}{d^2}$$

$$\frac{1}{100-d}=\frac{1}{3d} \quad \text{whence } d=25 \text{ cms.}$$

16. Light from a 32 c.p. lamp falls on a silvered mirror and is reflected thence to a grease-spot photometer. The distance from the lamp to the screen *via* mirror is 15 cms. If the mirror reflects 90 percent of the light falling on it where must a 8c.p. lamp be placed in order that the grease-spot shall disappear.

Reflection from Plane mirrors :—

17. A plane mirror distant 10 cms. from an object is moved back 10 cms. parallel to itself. How far does the image move?

18. The image of the moon 32° above the horizon is observed in a tranquil pool. Find the angle of incidence and reflection.

Angle of incidence $=90^\circ-32^\circ=68^\circ=$ angle of reflection.

19. What is the deviation produced by reflection on a plane mirror, when the angle between the incident and the reflected ray is 60°?

Hint—The deviation $=(\pi-60^\circ)$

20. A ray of light incident on one of two mirrors inclined at an angle to each other, in a direction parallel to the second mirror retraces its own course after reflection at the second mirror. Find the angle between the two mirrors.

Hint—The ray falls normally on the second mirror.

21. Find the angle between two mirrors in order that a ray incident on the first and parallel to the second may after reflection at the two be parallel to the first. Illustrate your answer by a figure.

22. The number of images due to a source of light between two mirrors inclined to each other being given by the formula $\frac{2\pi}{\theta}-1$ where θ is the inclination between the mirrors, find the number of images for the following values of θ (1) 0° (2) 10° (3) 30° (4) 45° (5) 60° (7) 90°. What happens when the two mirrors are parallel? Draw the figure in each case.

Spherical mirrors ;—

The connection between the focal length f and the distances u and v of the object and its image produced by a spherical mirror is given by the formula

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

where $f=r/2$, r being the radius of curvature of the mirror.

Again, it is to be remembered that f is *positive* for a *concave* mirror, and *negative* for a *convex* mirror.

Magnification produced is given by

$m=\frac{I}{O}$ where I=linear dimension of the Image

$\frac{v}{u}$ also.

23. A bright object 4 inches high is placed on the principal axis of a concave spherical mirror at a distance of 15 inches from the mirror. Determine the position and size of the image, the focal length of the mirror being 6 inches.

Here we have

$$\frac{1}{v}+\frac{1}{15}=\frac{1}{6} \text{ or } v=10 \text{ in.}$$

Again $\frac{I}{O}=\frac{v}{u}$, but $\frac{I}{O}=\frac{I}{4}$

Hence $\frac{I}{4}=\frac{10}{15}$ or $I=2\frac{2}{3}$ in.

Thus the image is 10 in. in front of the mirror and is $2\frac{2}{3}$ in high.

24. A candle flame is placed 25 cms. away from a concave mirror whose radius of curvature is 80 cms. Find the position and nature of the image.

25. In what position must a candle flame be placed in front of a concave mirror of focal length 40 cms. in order to give rise to an image four times as large as the object?

We have $m=\frac{v}{u}=\frac{I}{O}=4$

$\therefore \quad v=4u$

Then $\frac{1}{4u}+\frac{1}{u}=\frac{1}{40}$ whence $u=50$ cms.

Thus the candle must be placed 50 cms from the object for the real image.

Again, for *virtual* image, where v is *negative* we have

$$-\frac{1}{4u}+\frac{1}{u}=-\frac{1}{40}. \quad \text{whence } u=30 \text{ cms.}$$

26. Where must a candle be placed in front of a concave mirror of radius of curvature 80 cms. in order that a real image five times as large as the object may be formed.

27. The linear dimension of an object placed in front of a convex mirror of 3 in. focal length is twice that of the image Determine the position of the image and that of the object.

Here, $m=\frac{I}{O}=\frac{v}{u}=-\frac{1}{2}$ $\qquad u=2v.$

whence $\frac{1}{2v}+\frac{1}{v}=-\frac{1}{f}=\frac{1}{3}$ $\qquad$ whence $v=-9/2$ and $u=9$.

28. At what distance from a concave mirror of focal length f must an object be situated so that the image may be (i) of the same size (ii) one-quarter of the size of the object?

29. Determine the size of the image of an object held at a distance equal to its focal length in front of a convex mirror. Glazal

30. At what distance from a concave mirror must an object be placed so that its image shall be magnified n times.

The distance will depend on f, the focal length of the mirror since the magnification is to be n times the object, we must have

$$\frac{I}{O}=\frac{v}{u}=m$$

Or $\qquad v=n \cdot u$ (numerically)

Here care should be taken to notice the *signs* of v and u. In the case of a *real* image v and u are positive and $v=n\,u$; but when the image is virtual, v is negative and $=-n\,u$.

Thus there are two solutions

(i) Image real.—In the equation

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

Putting $\qquad v=n\,u \qquad$ we get

$$\frac{1}{nu}+\frac{1}{v}=\frac{1}{f}; \qquad \text{whence} \qquad u=(n+1)f/n.$$

(ii) Image virtual.—Substituting in the above equation $v = -n\,u$ we get

$$\frac{1}{u} - \frac{1}{nu} = \frac{1}{f}$$

Or $(n-1)/nu = \frac{1}{f}$ whence $u = (n-1)f/n$.

31. A concave mirror of 2 ft. focal length is placed 1 ft. from an object. Find the change in the position of the image produced by moving the object 1 in. nearer the mirror.

Here $f = 24$ in. and $u = 12$ in.

Then $1/v + \frac{1}{12} = \frac{1}{24}$ whence $v = -24$ in.

Again, when the object is moved 1 in. nearer, $u = 11$ in.

Hence $1/v + \frac{1}{11} = \frac{1}{24}$ whence $v' = -20{\cdot}3$ in.

i.e. the image moves through $(24 - 21.3) = 3.7$ inches

32. Prove that when an object is placed midway between a concave mirror and its principal focus the image is twice as large as the object,

33. An object 2 cms. high is placed 1 metre away from a spherical concave mirror of 23 cms. radius of curvature. Calculate the height of the image. Will it be real or virtual ?

34. An object is placed 13 cms. from a concave mirror whose focal length is 10 cms. Find where the image is. Is it real or virtual, erect or inverted, and what is its size, if the object be 42 m.m. broad and 14 m.m. long?

35. Determine the size and position of the image of an object 1 in. high placed 10 in. from a convex mirror 20 in. in radius.

The focal length being one half the radius of curvature is 10 in. and is negative, the mirror being convex.

Then the image is at a distance v given by

$$\frac{1}{v} + \frac{1}{10} = -\frac{1}{10}$$

Or $v = -5$ in.

Thus the image is virtual and is formed 5 in behind

For the size of the image we have

$$m = \frac{I}{O} = \frac{v}{u} = \frac{-5}{10} = -\frac{1}{2}$$

$I = -\frac{1}{2}$ in., the object being 1 in. high.

Thus the image is $\frac{1}{3}$ in. long and is inverted.

36. Find the nature, position and magnitude of the image of an object placed 50 cms. from a convex mirror of 15 cms. focal length. Verify graphically.

37. The radius of curvature of a convex mirror is 12 cms. and an object 2 cms. in length is held 3 cms in front of the mirror. Find the nature, position and magnitude of the image.

38. An image 2 in. long is formed by a convex mirror by an object placed 12 in. from it. Find the focal length of the mirror, length of the object being 6 in.

39. An object 2 in. long is held 4 in. from a convex mirror whose radius of curvature is 8 in. Find the position of the image.

40. When a gas flame is placed 32 cms. in front of a mirror, it is found that the image is 12 cms behind the mirror. Find the radius of curvature and the focal length of the mirror.

Since v is behind the mirror, it is negative.

Hence $-\frac{1}{12}+\frac{1}{32}=\frac{1}{f}$ whence $f=-19{\cdot}2$ cms.

and $r=-38{\cdot}4$ cms.

41. An object 2 m.m. in length is placed 35 cms. in front of a mirror and the real image is found to be 4 m.m. high. Find the focal length of the mirror. What is the focal length, if the image is virtual?

42. Determine the position and focal length of a mirror required to throw on a wall the image of an object, magnified 6 times and distant 15 cms. from the wall.

43. An object stands 12 cms. from a wall. It is required to throw an image magnified 5 times on the wall. State what sort of mirror you require and find the focal length of the mirror.

Hints:—$m=\frac{v}{u}$ or $v=5u$

and $u+12=5u$ or $u=3$

$\therefore\ v=15$. Hence etc.

44. A concave and a convex mirror, each 20 cms. in radius, are placed opposite to each other and at 40 cms. apart on the same axis. An object 5 cms. high is placed midway between them. Find the position and size, if the image is formed by reflexion first at the convex, then at the concave mirror. Trace carefully a ray from a point on the object to its image.

For reflection at the convex mirror, we have

$$u=20 \qquad \text{and} \qquad f=-10$$

$$\frac{1}{v}+\frac{1}{20}=-\frac{1}{10} \qquad v=-20/3$$

Again, for reflection at the concave mirror

$$u=40+20/3=140/3 \text{ and } f=10$$

$$\frac{1}{v}+\frac{3}{140}=\frac{1}{10} \qquad \text{or} \qquad v=140/11$$

Now for magnification, that due to the convex mirror.

$$\frac{I}{O}=\frac{v}{u} \qquad i.e. \quad \frac{I}{5}=\frac{20/3}{20}$$

And owing to the concave mirror

$$\frac{I}{O}=\frac{I}{5/3}=\frac{v}{u}$$

Here $v=140/11$ and $u=140/3$ $\therefore$ $v/u=3/11$

So that $\frac{I}{5/3}=3/11$ $\qquad$ *i. e.* $I=5/11$

45. An object is placed at a distance of 8 inches from a concave mirror 1 ft. in radius. A plane mirror inclined at 45° to the axis of the concave mirror passes through its centre of curvature; find the position of the image formed by reflection, first at the concave, then at the plane mirror.

For reflection at the concave mirror we have

$$u=8, f=6$$

$$\therefore \quad \frac{1}{v}+\frac{1}{8}=\frac{1}{6}$$

or $\qquad v=24$ in. from the concave mirror *i.e.* 12 inches from the plane mirror.

$\therefore$ its image due to the plane mirror is on a line perpendicular to the axis and distant 1 ft. from the centre.

Refraction at a Plane Surface ;—

46. A ray of light passes from one medium to a second making an angle of incidence=45° and an angle of refraction=30°. Find the refractive index for the medium.

$$\mu = \sin 45^\circ/\sin 30^\circ = \frac{1/\sqrt{2}}{\frac{1}{2}} = \sqrt{2}.$$

47. A ray of light is incident at 60° to the normal, upon a polished glass surface. The refracted ray makes an angle of 90° with the reflected ray. Find the refractive index for glass.

48. Explain why a straight stick partly immersed in water in an oblique position appears bent at the surface of the water.

49 A ray of light is incident on a glass plate at an angle of 60° and the refractive of index of the glass is $\sqrt{3}$. Find the angle of refraction.

50. The critical angle for a given medium is 60°. Find the refractive index for the medium.

$$\text{Here } \frac{1}{\mu} = \sin\ 60^\circ = \frac{\sqrt{3}}{2} \ \therefore\ \mu = \frac{2}{\sqrt{3}} = 1{\cdot}15.$$

51. The sine of the critical angle for two media is $\frac{7}{8}$. What is the value of the refractive index from the rarer to the denser medium?

52. The refractive index of water and turpentine are 1·33 and 1·47 respectively. Find the critical angle for a ray passing from turpentine to water.

*If $_{\alpha}\mu_{\beta}$ be refract. index from air to another medium

and $_{\alpha}\mu_{\gamma}$ " " " a second medium

Then $_{\gamma}\mu_{\beta}$ " from the first medium

to the second is given by $_{\alpha}\mu_{\beta} \div {}_{\alpha}\mu_{\gamma}$

$\therefore$ in this case since $\mu_{\beta} = 1{\cdot}33$ and $_{\alpha}\mu_{\gamma} = 1{\cdot}47$.

$_{\gamma}\mu_{\beta}$ i.e. the refractive index from turpentine to water

$$= \frac{1{\cdot}33}{1{\cdot}47} = {\cdot}905 \text{ app.}$$

the required critical angle

$$= \text{Sin}^{-1}\, {}_{\gamma}\mu = \text{Sin}^{-1}\, {\cdot}905 = 64^\circ{\cdot}8.$$

53. Find the absolute refractive index for a liquid, given that the relative refractive index from the liquid to glass is 0·9 and the absolute refractive index of glass is 1·512.

54. Find the refractive index from glass to water from the following data :—

Refractive index for air and water $= \frac{4}{3}$

" " " " " glass $= 1{\cdot}5$.

55. Explain the apparent rising of a picture stuck on to the bottom of a cube of glass so that it appears to an eye looking down as if it were in the glass. If the index of refraction be $1{\cdot}6$, how much does the picture appear raised to perpendicular vision ?

If a be the thickness of the cube, then we know that the virtual image of the picture appears raised than the object itself, the distance between the object and the image being—

$$a(\mu - 1)/\mu \qquad \text{where } \mu = 1{\cdot}6 \text{ from above.}$$

$\therefore$ Substituting we get $\dfrac{a \times {\cdot}6}{1{\cdot}6} = \frac{3}{8}a$

i.e. the image appears raised by 3/8 th. of the thickness of the cube.

56. A rectangular piece of glass plate ($\mu = 1{\cdot}6$) is put between the eye of an observer and an object. Find the alteration that takes place in the apparent distance of the object from the eye, the glass plate being 5 in. thick.

57. A vessel is 6 in deep and and filled with alcohol. What is the apparent depth of the liquid ?

58. A vertical microscope is focussed on a mark on the bench. A plate of glass 2 in. thick is then interposed ; the microscope is now raised through 2/3 in. for the mark to be still in focus. What is the refractive index for glass ?

Here we have the thickness of the plate $a = 2$ in. Then the mark will appear raised when viewed through the glass by an amount.

$$a(\mu - 1)/\mu = 2/3$$

i e. $\quad 2(\mu - 1)/\mu = 2/3$ or $\mu = 3/2$.

59. A mark is made on the bottom of a small trough of glass placed under a microscope so that the mark is in focus ; water is now poured on the trough to a depth of 4.6 cms. and the resulting displacement of the image is 1.15 cms. Find the refractive index for water.

60. The angle of a prism is 60° and its refractive index is 1.414. Prove that the angle of minimum deviation for a ray passing through it, is 30°.

It can be shown that when a ray of light passes through a prism of angle A and in the position of minimum deviation, then

$$\mu = \text{Sin}\,\frac{A+\delta}{2}/\text{Sin}\,A/2$$

where δ = angle of minimum deviation.

Here $A = 60^\circ$ and $\mu = 1.514$.

Then $1.414 = \text{Sin}\frac{(60+\delta)}{2}/\text{Sin}\,30^\circ$

or $\text{Sin}\,(30+\delta/2) = 1.414/2 = \sqrt{2}/2 = 1/\sqrt{2} = \text{Sin}\,45^\circ$

whence $\delta = 30^\circ$.

61. The angle of a prism is 60° and the minimum deviation of a ray when the prism is filled with a certain liquid is 30°. Find the refractive index af the liquid.

62. An equilateral hollow glass prism is filled with a certain liquid of refractive index 1·7. Trace the path of a ray incident on the prism at an angle of 30° with the surface.

Refraction through Lenses ;—

The connection between the focal length f and the distances u and v of the object and its image produced by a lens is given by—

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

where f is positive in the case of a concave lens and negative in the case of a convex lens.

Again, the magnification isgiven by

$$m = \frac{I}{O} = \frac{v}{u}$$

$$= \frac{\text{distance of Image from lens}}{\text{distance of Object from lens}}$$

63. A small object 1 inch in length is placed at a distance of 3 feet from a convex lens of focal length 1 foot. Where and of what size is the image? Illustrate your answer by a figure.

Here $u=3$ ft. and $f=-1$ ft.

On substituting in the formula

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

We get $\frac{1}{v}-\frac{1}{3}=-1$ or $v=-{}^{3}/_{2}$ ft.

Again $\frac{v}{u}=\frac{I}{O}$ or $\frac{I}{1}=\frac{3/2}{3}$ i.e. $I={}^{1}/_{2}$ in.

Thus the image is 18 in. behind the lens and ${}^{1}/_{2}$ in. high.

64. A small bright object is placed 10 cms. away from a concave lens of focal length 20 cms. Find the position of the image. Is it real or virtual?

65. An object is placed at the principal focus of a lens. Where is the image?

66. An object is placed 24 cms. away in front of a convex lens of 12 cms. focal length. Find where the image is.

67. An object is placed 12 inches from a convex lens of 8 in. focal length. Find the position and nature of the image.

68. An object, 3 cms. long is placed 10 cms. from a concave lens of 20 cms. focal length. Find the size and nature of the image.

69. An object of length 2 inches is placed at a distance of 6 ins. from a convex lens of 4 inches focal length. Find the position and length of the image.

70. A convex lens of focal length 18 cms. has an image formed by an object placed 24 cms. in front of the lens. Determine the position of the image.

71. In a convex lens of focal length f the object and image are of the same size. Find the distance of the object from the lens. Also determine the position of the object so that the image formed by the lens may be one-half the size of the object.

72. If an observer's eye be held up close to a convex lens of 3 cms. focal length to view an object at a distance of 25 cms. from the lens, show that the magnifying power is 6.

Here $u=2.5$ and $f=-3$

Hence substituting in the usual formula, we get

$$\frac{1}{v}-\frac{1}{2\cdot5}=-\frac{1}{3} \quad \text{whence} \quad v=-15$$

$$m=\frac{I}{O}=\frac{15}{2.5}=6.$$

73. The image of a small bright object placed 20 cms. from a lens is formed at a point 40 cms. on the other side of the lens. Find the focal length and the nature of the lens.

74. A virtual image of an object 25 cms. from a lens is formed on the same side of the lens and at a distance 8 cms. from it. What kind of a lens is it and what is its focal length?

75. A circular disc 1 m.m. diameter is placed at a distance of two feet from a convex lens and a virtual image 1 foot in diameter is formed. Find the focal length of the lens.

76. A candle flame placed 30 cms. in front of a lens is brought to a focus 8 cms. behind. Find the nature of the lens and its focal length.

77. The focal length of a concave lens being 20 cms, find the position of an object so that its image may be $\frac{1}{8}$th its own size.

78. An image magnified about 3 times is to be thrown on a screen by a convex lens of focal length 44 cms. Determine the position of the object which will give (1) a real, (2) a virtual image of the required size.

Suppose u aud v to be the reqd. distances of the object and the image from the lens. Since the image is to be three times the size of the object, its distance from the lens must be three times as great or $v=3u$ (numerically). But since the image is to be real, it must be formed on tbe *opposite* side of the lens, thus v is *negatiae* and $=-3u$. Then in the usual equation putting $f=-44$ and $v=-3u$, we get

$$-\frac{1}{3u}-\frac{1}{u}=-\frac{1}{44} \text{ whence } u=58{\cdot}7 \text{ cms.}$$

Now for a virtual image we must have v positive and $=3u$ (numerically). Then in the equation putting $v=3u$ and $f=-44$, we have

$$\frac{1}{3u}-\frac{1}{u}=-\frac{1}{44}, \text{ whence } u=29{\cdot}3 \text{ cms.}$$

79. A candle flame stands at a distance of 25 cms. from a wall. In what position must a convex lens of 3 cms. focal length be placed between them so as to produce on the wall a distinct image of the candle?

80. An image magnified about 4 times is to be thrown on a screen by an object distant 80 cms. from the sceen. Determine the nature and position of the lens to be used.

Combination of Lenses.—

If two lenses of focal length f_1 and f_2 are placed in contact, then the focal length f of the combination is given by—

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}$$

81. A convex lens of 10 in. focal length is combined with a concave lens of 6 in. focal length. Find the focal length of the combination.

Here $f_1=-10$ and $f_2=6$

Hence $\frac{1}{f}=\frac{1}{6}-\frac{1}{10}=\frac{1}{15}$ $\therefore$ $f=+15$ *i.e.* the combn. is concave.

82. Find the focal length of a lens which is equivalent to two thin convex lenses of focal length 10 cms. and 15 cms respectively.

83. A convex lens of 12 cms. focal length is placed in contact with a concave lens and the focal length of the combination is —24 cms. Find the focal length of the concave lens.

Power of a lens.—

The power of a lens is the reciprocal of its focal length *i. e.*$=1/f$

The power of a combination = algebraic sum of the powers of the constituant lenses.

84. Find power of (1) a convex lens of focal length 20 cms. and (2) a concave lens of focal length 10 cms.

85. The power of a concave lens is $+2$. It is placed in contact with a convex lens of power-5. What is the power of the combination ?

Defects of Vision.—

86. The distance of most distinct vision for a person is 20 cms. and he uses a reading lens of 4 cms. focal length. Find the magnifying power of the lens. Where must the lens be held in order that he may clearly read a book.

The image ought to be formed at a distance of 20 cms.

Hence $\frac{1}{20}-\frac{1}{u}=-\frac{1}{4}$

Whence $u=4$ *i. e.* lens must be 4 cms. from the book.

Again $$m = \frac{v}{u} = \frac{20}{4} = 5.$$

87. The nearest distance of distinct vision for a long-sighted person is 50 cms. and he uses convex spectacles of 30 cms. focal length. Find how much will he increase his range of distinct vision.

By using a convex lens objects at a distance u can have their image formed at a distance of 50 cms. from the eye and u is determined by the relation

$$\frac{1}{50} - \qquad \frac{\cdot}{30} \text{ whence } u = 18.75.$$

Thus the range is increased through $(50 - 18.75)$ or 31.25 cms.

88. A short-sighted person has distinct vision at 5 in. What kind of a lens should he use and of what focal length to enable him to read a book 20 in. from his eyes.

Here the image of the book, distant 20 in. from the eye must be formed at a distance of 5 in. from the eye.

Hence $\frac{1}{5} - \frac{1}{20} = \frac{1}{f}$ whence $f = +\frac{20}{3}$ in.

$\therefore$ the lens should be *concave* and of focal length $6\frac{2}{3}$ in.

89. The distance of distinct vision for a short-sighted person is 15 cms. Find the focal length of the lens to be used in order that he may see clearly an object distant 50 cms. from his eyes.

90. Find the nearest distance of distinct vision for a long-sighted person who uses convex spectacles of 40 cms. focal length when he cannot comfortably see through these spectacles objects nearer than 30 cms.

Here evidently the nearest distance of distinct vision with the lenses on is 30 cms. and without the lenses this must be where an image is formed, by the lens of 40 cms. focal length, of an object, held 30 cms. from the eyes.

This is given by $\frac{1}{v} - \frac{1}{30} \qquad 40$

Whence $v = 120$ cms. being the required distance of distinct vision.

91. A person who can see most clearly at a distance of 4 in. requires spectacles enabling him to see clearly things at a distance of 1 ft. Calculate the focal length of the spectacles required and show by a diagram how they act in the case.

CHAPTER V.

SOUND.

Wave-length of a Note :—

Wave-length of a note can be determined from the formula

$$v = n\lambda \text{ where}$$

v = velocity of wave motion
n = number of vibrations
λ = wave-length.

1. Establish the relation between the wave-length and velocity of wave-motion in a free medium.

2. What is the wave-length of a note of 400 vibrations a second, when the velocity of propagation is 1000 ft. per second ?

3. A body vibrating with a frequency of 100 sends waves 10 cm. long through a given medium. Find the velocity in this medium.

4. Longitudinal waves 5 cm. long travel through a medium with a velocity of 1100 cm. per second. Find the frequency of vibration of the body ?

We have $v = n\lambda$, here $v = 100$ cms. per sec and $\lambda = 5$ cms.

$\therefore \quad 1100 = 5n$ whence $n = 220$.

Velocity of Sound in an Ordinary Gas :—

This has been proved to be given by

$$V = \sqrt{\frac{P \times k}{D}}$$

where V = velocity of sound
P = atmosphere pressure
k = a constant
D = density of the gas.

5. Calculate the velocity of sound in hydrogen gas, assuming its velocity in air, and having also given that 1 litre of hydrogen weighs 0·0896 gm., and 1 litre of air 1·293 gm.

In an open space *i.e.* under ordinary atmospheric pressure the velocity of sound in air is given by

$$V_1 = \sqrt{\frac{P \times k}{D_1}}$$

For the velocity of sound in any other gas under similar conditions, we have

$$V_2 = \sqrt{\frac{P \times k}{D_2}}$$

$$\frac{V_1}{V_2} = \sqrt{\frac{D_2}{D_1}}$$

But here $V_1 = 330{\cdot}6$ and $D_2/D_1 = {\cdot}0896/1{\cdot}293$.

$\therefore$ substituting $\dfrac{330{\cdot}6}{V_2} = \sqrt{\dfrac{{\cdot}0896}{1{\cdot}239}}$

whence $V_2 = 1286$ metres per second.

6. A flash of lightning is observed and the thunder is heard four and half a seconds afterwards. How far away did the flash occur?

Velocity of Sound at any Temperature :—

$$V = V_0\,(1 + {\cdot}00183t) \text{ where}$$

V_0 = velocity at 0°C

V = „ „ the temp. t.

On an average for each centigrade degree rise of temp. the velocity of sound increases by 61 cms. per sec. or by about 2 ft. per sec.

7. The volocity of sound in air at 0°C is 332 metres per sec. ; find the temperature at which the velocity is 340 metres per second.

The velocity of sound at t°C is given by

$$V = V_0(1 + .00183\ t)$$

where V_0 = velocity at 0°C

Here $340 = 332(1 + .30183\ t)$

whence $t = 13$°C app.

8. A stone is dropped into a well 600 ft. deep. What time will elapse before the sound of the splash is heard at the top? Temp. of air within the well is 25°C.

9. A person makes a sound by clapping his hand in front of a wall, and hears the echo $\frac{1}{4}$ sec. afterwards. What is his distance from the wall? Temp. of air is 20°C

The sound first travelled from the person to the wall and the echo originated at the wall then travelled from the wall to the person, so that it took $\frac{1}{8}$ the sec. to travel the distance from the wall to the person.

Again velocity of sound at 20°C

$$=1093+2\times20 \text{ ft.}=1133 \text{ ft.}$$

$\therefore$ distance of the wall $=1133\times\frac{1}{8}=141$ ft. app.

10. An echo repeats four syllables. Find the distance of the reflecting surface. The velocity of sound is 1120 ft. per sec.

11. Two observers are stationed at a distance of $\frac{1}{4}$ a mile and $\frac{1}{2}$ mile respectively from a ringing church-bell. Compare the intensities of sound received by the two persons if there is no reflection of the sound in the way.

Beats:—

The number of beats per second between two sounds of nearly the same frequency is given by

$$m=n-n_1.$$

12. The vibration frequencies of two tuning-forks are 340 and 344. Describe what will happen when the two forks are sounded simultaneously. How will you find which fork has the higher pitch?

13. A sonometer string is tuned with a C fork ($n=256$). A fork X produces 5 beats per second with the string. A small piece of wax is then attached to one of the prongs of X and the frequency of the beats is increased to 7 per second. What is the natural frequency, when unloaded, of the fork?

The number of beats per sec. is equal to the diff. in the frequencies of the two forks.

This difference is 5 in the first case.

Again, since the number of beats is increased when the fork X is loaded with wax, the frequency of the fork is less than that of C.

Hence the reqd. frequency is $256-5=251$.

Frequency of a Note ;—

14. Describe some form of Syren. Explain how you will use the same to find the frequency of a note from an organ pipe.

If there are 40 holes in the disc of a syren, which revolves at the rate of 1020 per minute, what is the frequency of the note emitted?

If there are m holes in a Syren and n revolutions per sec. the frequency of the note is given by

$$N=m.n$$

Here $m=40$ and $n=1020/60=17$

$$N=40\times 17=680.$$

15. The disc of a siren contains 32 holes. How many revolutions must it take per minute to emit a note which is an octave higher than the middle C ($n=356.$)

16. A toothed wheel is made to touch a card as it rotates. The note emitted is found to be in unison with a C fork ($n=256.$) If the number of teeth be 30, find the speed of the wheel per minute.

17. An air-jet is made to play on a ring of 48 equidistant holes in a circular disc that is made to rotate at a constant speed of 10 per second. What is the frequency of the note emitted?

Vibration of a string.—

When a string vibrates, its frequency n is given by

$$n=\frac{1}{2l}\sqrt{\frac{T}{m}}$$

where T=tension in absolute units of force (dynes or poundals).
m=mass per unit length of the string
and l=length of the string.

18. Find the pitch of the fundamental note of a string from the following data:—

Length of the string—53 cms.
Mass per cm. length of string—·00323 grams.
Stretching weight—4000 grams.

The frequency n is given by

$$n = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

Here $T = 4000 \times 911$ dynes, $l = 53$ cms. and

$m = 0{\cdot}00323.$

$$\therefore \quad n = \frac{1}{106}\sqrt{\frac{4000 \times 981}{{\cdot}00323}} = 329 \text{ app.}$$

19. A stretched string $4\frac{1}{2}$ ft. long is made to be in unison with a tuning-fork of frequency 287. Calculate the rate of vibration of the string when its length is reduced to $3\frac{1}{2}$ ft.

20. Two similar strings are in unison. One is 60 cm. long and stretched by 12 kilogrammes. Find.

(1) the tension of the wire, if its length is 45 cm.

(2) The length of the wire when it is stretched by 20·5 kilos.

As the strings are in unison, we have

$$n = \frac{1}{2l}\sqrt{\frac{T_1}{m_1}} = \frac{1}{2l^1}\sqrt{\frac{T_2}{m_2}}$$

Here $m_1 = m_2$ the strings being similar.

Then $\frac{\sqrt{12}}{120} = \frac{\sqrt{T_2}}{90}$

Whence $T_2 = 6{\cdot}75$ kilos,

In the second case, we have $l = 60$. $T_1 = 12$. $T_2 = 20{\cdot}5$

Substituting in the above formula, we have,

$$l^1 = 78{\cdot}5 \text{ cms.}$$

21. A monochord emits a note of frequency 120. What will be the frequency of the note emitted by the same string if its tension be increased in the ratio of 4 to 9 and its length in the ratio of 5 to 6.

22. A wire gives out the note C ($n = 256$) when the tension on it is 10 kg. What tension will be required so that the string may emit its first lower octave?

Where is the bridge to be placed under the wire so that the latter may yield its second higher octave?

Here $256 = \frac{1}{2l}\sqrt{\frac{T}{m}}$

The first lower octave will have half the frequency of the given note

$$128=\frac{\cdot}{2l}$$

$$256:128=\sqrt{10}:\sqrt{T} \qquad i.e. \qquad T=2{\cdot}5 \text{ kilos.}$$

In the second case where the frequency of the second higher octave is four times that of the given note, we have, $1:4=l':l$

Whence $l'=\frac{1}{4}\,l$.

23. A string 50 cms. long, stretched by a weight of 10 kg. makes 256 transverse vibrations per second. How could the frequency of the note emitted be raised to 384 (1) by altering the length of the string, (2) by altering the stretching weight?

Organ pipes, Closed and Open :—

For a closed pipe to sound its fundamental we have the formula—

$$\lambda=4l$$

But $V=n\lambda$ hence $=4nl$

In the case of the fundamental note of an open pipe

$$\lambda=2l$$

Again $V=n\lambda=2nl$, where

V = velocity of sound,
n = frequency of the note.
λ = wave-length " "

24. What must be the length of a closed organ pipe which produces the note C ($n=256$) and that of an open pipe sending the note E ($n=320$). The velocity of sound is 1152 ft. per sec.

In the case of a closed pipe

$\lambda=4l$ and $V=n\lambda=4nl$

Here $1152=4\times256\times l$ whence $l=1{\cdot}11$ ft. app.

In the case of a ~~closed~~ open pipe

$\lambda=2l$ and $V=n\lambda=2nl$

Here $1152=2\times320\times l$ whence $l=1.8$ft.

25. The length of a pipe, open at both ends, that is in unison

with a certain fork. is 2 ft. the temperature being 15°C. Find the frequency of the fork. V = 1090 ft/sec.

26. The sound of an excited fork swells out loudly when held over a gas jar 6.4 in long and of 1 in. radius. Find the wave-length in air of the note emitted. Calculate also the vibration frequency of the fork. Temp is 20°C.

This is a case of resonant column of air and the length of the vibrating column.

$$=l+.6r \text{ (making the end correction).}$$

Then $V=4n(l+.6r)$

Again velocity of sound at 20°C is 1133 ft. per sec.

$\therefore$ $1133=4n(l+.6r)=4n(6.4-.6)/12$

Whence $n=485$ app.

Again, $V=n\lambda$

i. e. $1133=485\lambda$ whence $\lambda=28$in. app.

27. A closed pipe filled with a gas gives the maximum resonance when a fork of frequency 256 is held over it. Velocity of sound in the gas is 1324 ft. per sec. Determine the length of the pipe.

28. A fork of frequency 30 produces resonance in a pipe closed at one end. It is 10 in. long and 2 in. in diameter and is filled with air. Find the speed of sound in air at the temperature of the experiment.

29. A siren disc has 32 holes. An open organ pipe sounding its fundamental is found to be in unison with the siren when it is making 1050 revolutions per minute. Find the length of the pipe. Temp of air is 15°C.

In the syren

$$N=mn=32\times1050/60=560.$$

In the open pipe

$$V=2ln$$

Again velocity of sound at 15°C = 1120 ft. per sec.

$\therefore$ $1120=2\times560\times l$

Whence $l=1$ ft.

CHAPTER VI.

MAGNETISM.

Laws of Magnetic Force :—

Let m and m' be the respective strengths of two magnet poles and d the distance between them. Then the force between them is given by

$$F=\frac{mm'}{d^2} \text{ where } F \text{ is measured in dynes.}$$

1. The respective strengths of two N-poles are 5 and 10 respectively and they are 10 cms. apart. Find the force of repulsion between them.

Here $m=5$, $m'=10$ and $d=10$

$\therefore$ $F=\frac{5\times10}{10^2}=0.5$ dynes.

2. A north pole of strength 4 is placed 5 cms. from a south pole of strength 3. Find the nature and magnitude of these forces.

3. A north pole of strength 5 is placed 10 cms. from a south pole and the force exerted between them is 0.25 dynes : find the strengths of the south pole.

4. A south pole of strength 5 when placed 25 cms. from a north pole attracts the former with a force of 1 dyne. Find the strength of the north pole.

5. A force equal to the weight of four ounces is required to pull a small ball of soft iron from contact with one of the poles of a magnet A, and a force equal to the weight of nine ounces is required to pull the same ball off one of the poles of a second magnet B. Show the relative strengths of the magnets A and B.

6. A magnet pole of strength 72 attracts another distant 3 cms. from it with a force equal to the weight of a gramme. What is the pole strength of the latter ?

Hint—Force=wt. of 1 gm=981 dynes

Intensity of Force :—

The intensity of magnetic force at a point is measured by the force exerted on an unit pole placed at the point.

7. Find the intensity due to a magnet pole of strength 81 at a point distant 9 cms. from it.

8. What is the strength of a magnet pole which is urged by a force of 3 dynes when placed in a field of intensity 0.3.

9. The length of a magnet is 5 cms. and it is placed in a field of intensity $H = 0{\cdot}18$. What is the moment of the couple required to deflect it (1) through an angle of 30° from the magnetic meridian. (2) at right angles to the magnetic meridian? The pole strength of the magnet is 3.

Here force acting on each pole $= 3 \times 0.18 = 0.54$.

(1) The arm of the couple $= 5 \text{ Sin } 30^\circ = 5/2$

$\therefore$ the moment of the couple $= 0.54 \times 5/2 = 1.35$

(ii) When the needle is at right angles, the arm of the couple $=$ length of the needle

$\therefore$ the moment of the couple $= 0.54 \times 5 = 2.7$.

CHAPTER VII.

FRICTIONAL ELECTRICITY.

Coulomb's Law

$$F = \frac{q \times q'}{d^2} \quad \text{where}$$

F=force in dynes.
q=quantity of electricity in one charge
q'= „ „ „ „ the other „
and d=distance between them „

1. Two small insulated metal spheres charged respectively with 45 and 5 units are placed one metre apart. What is the direction of the resultant electric forces exerted on a small + charge at a point one metre distant from the centres of each of the spheres?

Here force due to the charge+5 on the small charge q say,

placed 1 metre apart $=\frac{5 \times q}{100^2}$

That due to the charge—5 $=\frac{5 \times q}{100^2}$

The former being repulsive and the latter attractive while both are equal in dimension, their resultant is a force parallel to the line joining the centres of the spheres.

2. Two small insulated spheres are charged with +10 and —30 units respectively. The distance between the spheres being 5 cms what is the force of attraction between them?

3. The force of attraction between two bodies was 8 dynes when they were placed 6 cms. apart. What is the charge on each if the + charge was twice the—charge?

Here $\frac{qq'}{}$ =8 and $q=2q'$.

$\therefore$ we get $q = 24$ and $q' = -12$ units.

4. Two equally charged spheres repel each other when their centres are half a-metre apart with a force equal to the weight of 6 milligrams. What is the charge on each in electrostatic units?

Here weight of 6 mg. is equivalent to a force of

$$\frac{6 \times 980}{10 \times 10 \times 10} \text{ dynes}$$

Then
$$\frac{q^2}{50^2} = \frac{6 \times 980}{10 \times 10 \times 10}$$

$$\therefore \frac{q^2}{50^2} = (2.4)^2 \text{ app.}$$

$$q = 120 \text{ units.}$$

5. Electric charges of 10 and 5 units are given to two bodies which are at a distance of 50 cms. apart. At what point on the straight line joining the charges is the electric force zero.

Let x be the required distance from the charge of 5 units. Then its distance from the charge of 10 units is $50-x$, hence we have .

$$\frac{10}{(50-x)^2} = \frac{5}{x^2}.$$

Or $$x\sqrt{2} = 50 - x \qquad \text{whence} \quad x = 20.3 \text{ cms.}$$

6. Equal electric charges of 10 units each are placed on small conductors at two opposite corners of a square of 10 cms. radius. Calculate the electric force at either of the remaining corners.

7. A cake of shellac is rubbed with catskin. Show how to obtain from the shellac a +ve or −ve charge on an insulated conductor. How can you ascertain whether a given charge is + or without changing its amount?

Electric Potential ;—

It may be shown that if there is a charge q collected at a given point, the difference of potentials due to it at any two given points A and B, whose distances from the given point are r and r' respectively, is

$$V_A - V_B = q/r - q/r'$$

When B is at infinity or is connected with the earth r' becomes infinity and $q/r'=0$ for the potential of the earth be regarded as zero Tthe expression for the difference of potentials between A and the earth, or more briefly, the potential of the point A reduces to

$$V_A = q/r$$

If there are several charges namely, q_1, q_2, q_3, at distances r_1, r_2, r_3, respectively, then the potential at A due to all these charges is

$$V_A = q_1/r_1 + q_2/r_2 + q_3/r_3 +$$

The external action of an electrified spherical conductor is the same as if the whole charge were collected at the centre.

8. Charges of 10 units of + electricity are placed at the three corners of a square the side of which is 8 cms. Find the potential at the other corner.

$$\text{Here potential} = \frac{10}{8} \cdot \frac{10}{8} + \frac{10}{8\sqrt{2}} = 3{\cdot}4 \text{ app.}$$

9. Charges of 10 units of + veelectricity are placed at each corner of a square, the side of which is 8 cms. Find the potential at the intersection of the diagonals.

10. Charges of + 10, + 15, −5 aud −4 units of electricity are placed at the corners A, B, C, D respectively, of a square whose side is 10 cms. long. Find the potential at the middle point of CD

$$\text{Here potential} = \frac{10}{5\sqrt{5}} + \frac{15}{5\sqrt{5}} - 1 - \tfrac{4}{5} = {\cdot}436 \text{ app.}$$

11. Charges of 10, 20 and 30 units of + electricity are placed at the corners A, B and C respectively of a square whose sides are 10 cms long. Find the potential at the corner D and at the centre O. Find the amount of work necessary to be done to bring a + unit from D to O.

Electrical Capacity of a Body.—

The capacity of any conductor is measured by the quantity of electricity required to raise its potential from zero to unity.

Again, the potential of a conductor depends both upon its amount of charge and upon its capacity; in fact if C be the

capacity of a conductor, Q the quantity of electricity with which it is charged, and V its potential, then

$$C=\frac{Q}{V} \text{ or } Q=CV.$$

Again, if a number of conductor of capacities C_1, C_2, C_3 etc. at considerable distances apart, have potentials V_1, V_2, V_3 etc. then when they are joined together by fine wires (of negligibly small capacities), their common potential V is given by

$$V=\frac{V_1 C_1+V_2 C_2+V_3 C_3 + \text{etc.}}{C_1+C_2+C_3+\text{etc.}}$$

12. Find the quantity of electricity which must be given to an insulated sphere 6 cms. in diam. so that its potential may be raised from zero to 15.

The capacity of the sphere, being equal to its radius is 3 cms.

Hence quantity reqd.$=3\times15=45$ units.

13. There insulated metal spheres at considerable distances apart are charged with electricity till their potentials are 2, 5, 7 respectively. If their radii are 2, 3, 4 respectively, find the potential of the whole system when they are connected by a fine wire.

Here the reqd. potential

$$V=\frac{2\times2+5\times3+4\times7}{2+3+4}=5\cdot2$$

14. If the radii of the spheres were 4, 5 and 6 cms. respectively and their initial potentials were 6, 7 and 8 respectively, find the potential of the whole system when joined by a wire.

15. The capacity of three spheres are 3, 2, and 1 respectively and their potentials are 1, 2 and 3: What is the common potential when they are all joined by a very fine wire?

16. Two insulated brass balls are joined by a long fine wire; one has a diam of 3 in. and the other a diam of 1 in. A charge of 48 units of + electricity is given to them. How will the charge be distributed?

Here, the potential of the two balls is the same, hence the charges of the two balls are proportional to their capacities ;

and the capacity of the first ball is 1.5 while that of the second is 0.5; then the charges are in the proportion 1.5 : 5 or 3 : 1; *i.e.* the charges are 36 and 12 units respectively.

17. A charge of 1000 units is given to two insulatad balls of capacity 10 and 15 units respectively. What is the charge on each ball and the potential of the system?

18. Two insulated metal balls are connected by a fine wire, one has a radius of 5 cms. and the other a radius of 8 cms. They are charged and on testing, the large one it is found to have a charge of 16 units. What was the total charge?

The charges are in the ratio of their capacities, then we have

$$4 \cdot 25 = 16 \cdot x$$

Or $$x = 10$$

$\therefore$ total charge $= 16 + 10 = 26$ units.

19. The diameter of a sphere is 5 cms. and it is charged until its surface density is $5/\pi$: What is its potential?

20. Two insulated and widely separated metallic spheres receive charges of positive electricity which raise their potential to 4 and 5 respectively. The densities of the charges being in the ratio 4 : 9, compare the radii of the balls.

The densities being in the ratio of 4 : 9 the charges are in the ratio of $(4\pi r^2 \times 4)$: $(4\pi r'^2 \times 9)$

Then since $$\frac{Q}{V} = C$$

we have $$\frac{4\pi r^2 \times 4}{4} = r$$

and $$\frac{4\pi r'^2 \times 9}{5} = r'$$

where r and r' are the radii and therefore the respective capacities of the two spheres.

Thus we have $r : r' = 1 : 1{\cdot}8$.

21. An insulated brass sphere of 4 cms. radius is brought into a region where the potential is 5. It is then brought into earth connection and removed. What is the free charge?

When the sphere is brought to the region of potential 5 it acquires a charge of 4×5 or 20 units of + electricity on one side and -20 units of $-$ electricity on the other side remote from

the first and when the sphere is connected to earth 20 units of + electricity pass to earth leaving 20 units of − electricity on the sphere.

22. An insulated brass sphere was brought into a region where the potential was 10, touched with finger and then removed. It was found to have 40 units of negative electricity on it. What was the radius ?

23. How much work has to be spent in charging a sphere from potential zero to 12, the diameter being 4 cms.

When the potential of a conductor is raised from 0 to V, the average potential is $\frac{V}{2}$ and the work done $=\frac{QV}{2}$.

Here $Q=CV=12\times2=24$ and $\frac{V}{2}=6$

$\therefore$ work done $=6\times24=144$ ergs.

24. If the radius of a sphere is 6 cms. how much work has to be expended on it to raise its potential from 0 to 50 ?

CHAPTER VIII.

CURRENT ELECTRICITY.

Resistance of a Conductor :—

The resistance of a conductor is directly porportional to its length and inversely proportional to the area of its cross-section.

If there are two uniform conductors of length l_1 and l_2 and of the same material, then the ratio of their resistances R_1 and R_2 is

$$\frac{R_1}{R_2}=\frac{l_1/s_1}{l_2/s_2}=\frac{l_1.s_2}{l_2.s_1}$$

s_1 and s_2 being the cross sections of the two conductors.

The resistance of a conductor also depends upon the material of which it is made. The *Specific Resistance* of a substance is defined as the resistance betweecn opposite faces of a unit cube of the substance.

Thus, if a conductor of length l and cross-section s has a specific resistance ρ. then its resistance is $\rho \times l/s$ in C. G. S. units: expressed in *ohms* its resistance is $\rho \times l/s \times 10^9$, for one ohm $= 10^9$ G. G S. units of resistance.

1. What is the resistance of a column of mercury 2 metres long and ·6 of a sq. m.m. cross. section at 0°C ?

Here length of mercury column is 200 cms. and cross-section is $·6/10^2$ sq. cms; also the specific resistance of mercury is 96×10^{-6} app.

Hence resistance of the column $=\frac{96 \times 10^{-6} \times 200 \times 10^2}{·6}$

$=3·2$ app

2. What length of copper wire, having a diameter of 3 m.m. has the same resistance as 10 metres of copper wire having a diameter of 2 m.m.?

Here cross-section of the wires are $\frac{\pi}{10^2}$ and $\frac{\pi \times (1{\cdot}5)^2}{10^2}$

Then $$l \times \frac{10}{(1{\cdot}5)^2 \times \pi} = 10 \times 100 \times \frac{10^2}{\pi}$$

Whence $$l = 22{\cdot}5 \text{ metres.}$$

3. An incandescent lamp takes a current of 0·5 amperes and the *E.M.F.* between its terminals is 90 volts; what is its resistance?

Here $R = E/C = 90/0{\cdot}5 = 180$ ohms.

4. A battery has an *E. M. F.* (on open circuit) of 20 volts. When the poles are connected by a wire the *E. M. F.* falls to 15 volts and a current of 2 amperes passes through. Find the internal resistance of the battery and the resistance of the copper wire.

When the circuit is made, we have

$C = 2$ amperes and $E = 15$ volts,

Then R, the resistance of the wire $= E/C = 15/2 = 7{\cdot}5$ ohms.

Now 15 volts is the potential difference that causes the flow of a current of 2 amperes through a wire of resistance 7·5 ohms; the total *E. M. F.* of the battery being 20 volts. Then if R' be the internal resistance of the battery, by Ohm's law, we have

$$20 = 2\,(7{\cdot}5 + R') \qquad \text{whence } R' = 2{\cdot}5$$

5. A current of 10 amperes flows through a conductor, the ends of which are found to have a difference of potential of 20 volts. What is its resistance?

6. An incandescent lamp of 100 ohms. resistance takes a current of 0·3 amperes. what is the *E. M. F.* reqd. to work it?

7. Compare the resistances of two similar wires one of which is nine times as long as the other.

8. Two exactly equal pieces of copper are drawn into wire; one into a wire 10 ft. long and the other into a wire 20 ft. long. If the resistances of the shorter wire is 0·5 ohms. what is the resistance of the longer wire?

Ohm's Law :—

With suitable units, Ohm's law may be expressed by means of an equation, thus—

$$C=\frac{E}{R}$$

where C=Current in *amperes*, E=E M.F. in *volts* and R=resistance in *ohms*.

If the Whole resistance R, be divided into the internal resistance of the cell r and the total external resistance of the cell R, then—

$$C=\frac{E}{r^1+nR}$$

Grouping of Cells ;—

(*a*) *In parallel*—In this arrangement with n cells Ohm's law becomes—

$$C=\frac{E}{r^1+Rn}$$

(*b*) *In series*—In this case Ohm's law becomes with n cells—

$$C=\frac{\quad}{nr^1+R}$$

(*c*) *Mixed circuit*—If we have n rows of m cells arranged in series then,

$$C=\frac{nmE}{mR^1+nr}$$

In this case, it may be proved that the current is maximum when R is equal to $\frac{mr^1}{n}$

9. Five Daniell cells, each having an *E.M.F.* of 1·08 volt, and an internal resistance of 4 ohms. are joined in series what will be the current produced with an external resistance of 5 ohms.

As the cells are joined in series, we have,

$$C=\frac{nE}{nR'+r}=\frac{5\times 1\cdot 08}{5\times 4+5}=\frac{5\cdot 4}{25}=\cdot 216 \text{ amperes.}$$

10. A certain cell has an internal resistance of 0·3 ohms and its *E. M. F.* on open circuit is 1·8 volt. When the circuit is completed by a copper wire of length 5 cms and resistance 1·2 ohm, the potential difference falls and a current passes through. Find this potential difference and also the current strength.

11. The *E. M. F.* of a battery being 12 and its resistance 8, find the strength of the current generated by it when its poles are connected (1) by a wire whose resistance is 16 (2) by a wire whose resistance is 40.

Here the *E. M. F.* on closed circuit is 12.

Hence (1) $C=\frac{12}{8+16}=0\cdot 5$ amperes

(2) $C=\frac{12}{8+40}=0\cdot 25$ amperes.

11. Ten voltaic cells, each of internal resistance 3 and *E. M. F.* 4 are connected—

(*a*) in a single series.

(*b*) in two series of 5 each, the similar ends of each series being connected together.

If the terminals in each case are connected by a wire of resistance 20, show what is the strength of the current in each case.

(*a*) This is the case of a group of cells joined in series then

$$C=\frac{nE}{nR'+r}=\frac{10\times 4}{10\times 3+20}=\cdot 8 \text{ ampere.}$$

(*b*) This is the case of a mixed circuit, then, we have

$$C=\frac{nmE}{mR'+nr} \quad \text{here } m=5 \text{ and}$$

$n=2$, then $C=\frac{40}{15+40}=\cdot 727$ ampere.

12. Find the best arrangement of 24 cells having an external resistance of 3 ohms. and each cell having an internal resistance of 2 ohms.

We know that with a *given* external resistance the maximum current with n rows of m cells in series is obtained when $r = \frac{mR'}{n}$ or $nr = mR'$. Thus we have to arrange the cells in such a way that the above condition may be satisfied.

Now, we have here $n \times m = 24$

and $r = 3$ and $R = 2$

$\therefore$ $3n = 2m$ i,e, $m = 3/2\ n$

then $n = 4.$ and $m = 6$

Thus, the arrangement is four rows of six cells in series.

Divided Circuits.—

If two points A and B of a circuit be joined by several wires of resistances r_1, r_2, r_3 etc. and if R be the equivalent resistance, then

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \text{ etc.}$$

Shunts.—

The current C_s passing through the shunt is given by

$$C_s = \frac{G}{S+G} C. \quad \text{where}$$

C = the total currrent
G = resistance of the galvanometer.
S = " " shunt.

and that through the galvanometer by

$$C_G = \frac{c}{G+S}$$

13. Two wires are joined in parallel, their resistances being 10 and 20 ohms, fine the resistance of the conductor thus formed.

Here $\frac{1}{R} = \frac{1}{10} + \frac{1}{20}$ whence $R = 6{\cdot}6$ ohms.

14. Three wires are joined in simple circuit, their resistances being 30, 40 and 50 ohms ; find the resultant resistance.

15. The resistance between two points A and B of a circuit is 30 ohms. but on adding a wire between A and B the resistance becomes 25 ohms, what is the resistance of the added wire ?

16. A galvanometer of 2000 ohms. is shunted with a wire of 1 ohm. resistance. Find the resistance of the shunted galvanometer.

17. A current of 4 amperes flows through a galvanometer of 200 ohms. connected with a shunt of 1 ohm. resistance. What is the current passing through the galvanometer ?

Here $$C_G = \frac{1 \times 4}{200+1}$$

$$= \cdot 019 \text{ amperes.}$$

18. A galvanometer of 40 ohms. resistance is shunted by a shunt of 5 ohms. Find the resistance of the shunted galvanometer and the current which flows through it when a difference of potential of 20 volts is maintained between its terminals.

19. A divided circuit consists of two wires of the same material whose lengths are l and l', and cross-sections s and s' respectively. determine the currents in the two wires.

Heating effect of a Current—

From Joule's Law, we have

$$J\,H = C^2Rt$$

i. e
$$H = \frac{C^2Rt}{J}$$

$$= \frac{C^2 \times R \times t \times 10^{-2} \times 10^9}{4 \cdot 2 \times 107}$$

$$= C^2Rt \times \cdot 24. \quad \text{where}$$

J=mechanical equivalent of heat$=4 \cdot 2 \times 10^7$ ergs.
R=resistance in ohms$=R \times 10^9$ in absolute units.
C=current in amperes$=C \times 10^{-1}$ in absolute units.
t=time for which the current flows.

20. The *E.M.F.* of a battery is 18 volts and its internal resistance 3 ohms. The difference in potential between its poles, when they are

connected by a wire A, is 15 volts, and falls to 12 when A is replaced by another wire B. Compare the amount of heat developed in A and B in eqnal times.

Heat developed in both cells in equal times is proportional to $C^2R=EC$.

In the first case, we have

$C=\frac{15}{R}$, R being the resistance of the wire, A.

And $18=C(3+R)$ whence

$C=1$ ampere

$\therefore$ Heat produced$=EC=15$

In the second case, similarly we have,

$EC=24$.

$\therefore$ their ratio$=15:24$.

21. A current of 1 ampere passes through a coil whose resistance is 2 ohms. what amount of heat is developed in the coil in 5 seconds.

Here $H=C^2Rt\times 24$

$=1\times 1\times 2\times 5\times \cdot 24$

$=2\cdot 4$ units.

22. A current of 10 amperes passes, through a wire whose resistance is 0·9 ohm. for 5 seconds. what amount of heat is developed

Tangent Galvanometer :—

In a tangent galvanometer, the current strength is given by

$C=KH\tan\theta$ where

K=the galvonometer constant

$=\frac{r}{2\pi n}$, r being the radius of the coil and n the no. of turns in the coil

θ=deflection in degrees on the scale.

and H=horizontal component of the Earth's field.

23. A current of 0·9 amperes flows through a tangent galvanometer consisting of 5 turns of wire, each of 20 cms. diameter :

what is the strength of the field due to the circular current at its centre? If the value of H at the place is 0·18 through what angle will the needle be deflected?

The strength of the mag. field produced by the current is measured by the force on a unit mag. pole and this is $2\pi nC/r$; and the ampere being one tenth of the *C. G. S.* unit of current the required strength of the field is

$$\frac{2\pi \times 15 \times 0{\cdot}9}{10 \times 10} = {\cdot}283$$

And the required deflection is given by

$$\begin{aligned}\tan\theta &= \frac{2\pi n}{r}\frac{C}{H}\\ &= \frac{2\pi \times 5 \times {\cdot}09}{10 \times 0{\cdot}18.} = \frac{{\cdot}283}{0{\cdot}18}\\ &= 1{\cdot}572\\ \theta &= 58^\circ \text{ app.}\end{aligned}$$

24. A circular coil of wire of 10 cms. radius each, consists of 3 turns what force will be exerted by a current of 0·04 amperes on a magnetic pole of strength 10 placed at the centre of the coil?

25. A very short mag. needle is suspended at the centre of a hoop of wire fixed vertically in the magnetic meridian. One current passing through the wire causes a permanent deflection of the needle amounting to 30°, another current causes a similar deflection of 45°. What are the relative strengths of the two current.

Hints—$C_1 : C_2 = \tan 30^\circ : \tan 45^\circ$.

26. In a tangent galvanometer a current of strength C causes a deflection of 30°, another of strength C′ causes a deflection of 45°. What is the relation of C to C′?

27. If an increase of the resistance of a circuit by 10 ohms. causes the strength of the current to decrease from 5 to 2, find the total resistance of the circuit after the change.

Let E be the E. M. F. and X be the resistance of the circuit, then, we have

(i) $\frac{E}{x} = 5$ and

(ii) $$\frac{-}{x+10}=2$$

whence $$x=6\cdot6 \text{ ohms.}$$

28. When a coil of wire is connected in circuit with a battery and a tangent galvanometer, the latter shows a deflection of 45°. If the wire is replaced by resistances of 24 and 25 ohms in turn, the deflection is 46° in the first case, and 44° in the second. Find the resistance of the wire. Tan $44^\circ=\cdot966$, tan $45^\circ=1$, tan $46^\circ=1\cdot036$.

Let r be the resistance of the circuit and R that of the coil of wire.

Then we have,

$$C=K \tan 45^\circ=K$$

$$\frac{E}{R+r}=K$$

Similarly $$\frac{}{r+24}=K\times1\cdot036$$

and $$\frac{}{r+25}=K\times\cdot966.$$

whence $$R+r \cdot r+24 =1\cdot036 \,.\, 1$$

and $$r+25 : r+24 =1\cdot036 : 966$$

Solving, we get $$R=24\cdot5 \text{ ohms.}$$

29. A cell was arranged in series with a tangent galvanometer and a resistance box. A deflection of 40° was obtained with a resistance of 8 ohms, and a deflection of 35° with 10 ohms. The resistance of the galvanometer and connecting wire was ascertained to be $1\cdot05$ ohms. Find the internal resistance of the cell. Tan $35^\circ=\cdot7002$, tan $40^\circ=\cdot8391$.

30. Six similar cells are arranged in series, and the circuit completed through a coil of wire and a galvanometer. The resistances of the battery, coil and galvanometer are 10, 50 and 20 ohms respectively. If the difference of potential between the terminals of the galvanometer be 2 volts, what is the E. M. F. of each cell of the battery?

Here current passing through $=\frac{E}{80}$ and as this passes through the galvanometer, we have

$$\frac{2}{20} \text{ or } \frac{1}{10}=\frac{E}{80} \quad \text{whence } E=8 \text{ volts}$$

$\therefore$ E. M. F. of each cell = 1·3 volts.

31. A battery of internal resistance 4 ohms and E. M. F two volts is connected to a wheatstone bridge arrangement and when balance is obtained the resistances in the arms of the bridge are 5, 15, 20 and 60 ohms. Find the current in the battery.

The equivalent resistance R of the bridge is given by

$$\frac{1}{R}=\frac{1}{20}+\frac{1}{80}$$

$$=\frac{1}{16}$$

$$R = 16 \text{ ohms.}$$

$$C=\frac{E}{R+r}=\frac{2}{16+4}=\cdot 1 \text{ ampere.}$$

Electrolysis ;—

The weight of ion liberated is given by

$W = zCt$ where

W=weight of ion in gms,
C =strength of current in amperes,
z =electro-chemical equivalent,
t =time in seconds.

32. How many amperes would deposit 2 gms. of copper in 15 minutes, the current being supposed constant ?

Here W=2 gms. $z=\cdot 0003276$ and $t=900$ secs.

$$\therefore \quad C=\frac{2}{\cdot 0295} \text{ amp.}$$

$$=6\cdot 78 \text{ amperes.}$$

33. How many gms. of copper would be deposited by a constant current of 12 amperes acting for one hour ?

34. 35 [illegible] 6 gms. of copper are liberated in 5 hours by a constant current of C [illegible]peres. Find the value of C.

35. What w[illegible]ould be the strength of a constant current which liberates 50 c.c. of hydrogen in 5 minutes ?

1 c.c. of hydrogen weighs ·0000896 gm.

∴ 50 c.c. " " ·00448 gm.

And from the equation $W = Cst$ we have-

$$C = \frac{W}{st}$$

Whence $$C = \frac{\cdot 00448}{\cdot 0000104 \times 300}$$

$$= 1\cdot 4 \text{ ampere.}$$

36. Four cells were arranged in series and on connecting the terminals to a water-voltameter it was observed that 250 c.c of hydrogen were liberated at the cathode in 15 min. 32 secs, find the current strength.

Comparison of Resistances by the Principle of Wheatstone's Bridge :—

In the Wheatstone Bridge arrangement, (See De's Practical Physics, page 270) when there is no current passing through the galvanometer, we have

$$\frac{P}{Q} = \frac{R}{S}$$

where P, Q and R are the known resistances in the three arms and S is an unknown resistance in the fourth arm. In a practical determination of an unknown resistance, the apparatus which is frequently used is the Metre-bridge or the Post-Office Box.

36. In a Wheatstone Bridge in which resistances of 10 and 100 ohms respectively were used as the fixed resistances, a wire whose resistance was to be determined was placed: its resistance was balanced when the adjustible coils were arranged to throw 281 ohms into circuit. What was the resistance?

37. A wire of resistance 5 ohms is connected in parallel with another and the whole joined to a wheatstone bridge arrangement. When balance is obtained, the resistances in the three arms of the bridge are 30, 10 and 12 ohms, respectively. Find the resistance of the added wire.

Let x be the unknown resistance. Then the resistance S, of the divided circuit is given by

$$\frac{1}{S}=\frac{1}{5}+\frac{1}{x}$$

And S is obtained from

$$\frac{P}{Q}=\frac{R}{S}$$

$$S=\frac{Q.R.}{P}=\frac{10\times 12}{30}=4 \text{ ohms}.$$

whence $x=20$ ohms.

39. An unknown resistance x and a coil of 10 ohms are put on the gaps of a metre bridge and balance is obtained when the jockey stands at 35 cms. from the end nearest the unknown resistance. Find the unknown resistance.

Hint :— $\frac{x}{10}=\frac{35}{100-35}$, whence x is found.

40. Two resistances of 10 and 30 ohms are put in the gaps of of a metre-bridge. At what position of the key there would be no current in the galvanometer ?

ANSWERS.

CHAPTER I. (pp 1-3)

3. 5·1 ft. 4. 69·09 ft. 5. 150
8. 24685 app. 9. 2·45 in; 156·8 in. 10. ·018 in.

CHAPTER II. (pp. 4-17)

2. 2·7 gms per c.c. 3. 2·89 oz. per cub in
4. 3360 gms. 5. 13600 gms. 6. ·03 cm.
8. 48361 lbs. 9. 1·7 c c. 10. 2 cub. ft.
11. 0·001118. 14. 1019·4 cms. 16. 22 gms. wt.
17 26·04 lbs. per sq. in. 18. 14·01.
19. 25 cms. 20. 1000 gms. on the upper surface 2000 gms. on the lower surface and 1500 gms. on the sides.
24. 500 c.c. 25. 100 c.c. 26. 8·88.
28. 4423 cub. yds. 29. Density, 0·2 gms. per c.c. and volume, 100 c.c. 30. 0·6
31. 5 lbs. 34. 30,000 oz per sq. ft.
35. 31 ft. 36. 20 ft. 37. ·4912 lb./sq. in.
40. 100·7 cms. 41. 52 cms. 43. 63 cms.
45. 0·0015 cub. in. 46. 4 c.c.
51. 0·35. 53. 2·5 54. 0·3 c.c.
56. 2·8. 57. 2·2. 59. 5 gms.
62. 17·5 gms. 64. 2·77 65. *misprinted.*
63 Mass of B is ·997 times that of A. 67. 3.
68. 1·625. 70. 0·6. 71. 0 25.
74. 0·75 75. Volume—250 c.c., specific gravity—4.
77. 13·92 gms. 78. Lead—11·42, oak—0·8507, alcohol—0·7971.
81 60·2 kgm. 83. 5 Strokes. 84. Rises 1·99 cm. in one limb and falls 1·99 cm. in the other; 65·9 cms. of oil reqd. 85. 27·2 in,

CHAPTER III. (pp. 18-41.)

2. (i) 68° (iii) 21°·2 (v) 121°.
(ii) 1562° (iv) —58° (vi) 212°.

3. (i) 110°. (iii) —23°·3. (v) 100°.
(ii) 2°·9. (iv) 45°. (vi) 0°.
6. 25·6. **7.** (ii) 100·255 cms. (iii) 100·85 cms.
8. 10·00321 yds. **9.** 100·012 cms. **10.** 60·072 ft.
12 0·03 cms. **13.** Platinum wire—2999·74 cms;
Brass wire—299·507 cms.
15. 866°.6 C. **16.** 30·018 in. **17.** 0·072 in
18 0·0000086. **19.** 58°·8C. **22.** 1·22 ft.
24. 0·01952 cms. **25.** 0·2196 yds. **26.** Iron—30 cms.
Copper—20 cms. **28.** 13·96 sec. a day
31. 100·38 sq. cms. **33.** 11000·37 cc.
34. 6·0016 litres. **36.** 284°·9C. **38.** 4·976.
39. 0·000259. **41.** 0·000066. **46.** ·000255

47. 0·000155. **48.** *misprinted 49*, 5·35 gms
49. *misprinted 50*, 0·0003
50. *misprinted 51*, 30°C. **53.** 2 litres.
54. 26 litres **55.** 1·293 gms. of air.
57. *misprinted* 58, 273°C.
58. *misprinted* 59, 10°C.
60. *misprinted* 60, 1/273. **62** 1/200
63 ·000243. **65.** 13·2 cc. **67.** (i) 1 litre app.
(ii) 1·38 litre. (iii) 0·8168 litre.
68. (*a*) 6·6 cc. (*b*) 622 cc. **69.** 78 cms.
70. —123°C. **74.** 76·23 cms. **75.** 190 m.m.
76. 150 cub. in. **77.** 28·9 in.
78. 45°45 C. **80.** (i) 350 heat-units (iii) 46°·6C
81. 0·1 **82.** 0·112 **85.** 0·1036.
87. 0·095 **88.** 0·057 **89.** 0·09.

90. 0·615 **91.** 0·427 **92.** 0·46.
94. 292°.5C. **95.** 1774°C **96.** 52·4 lbs.
97 67°·9C **98.** There would have been a rise of 2°·4C.
100. 3180 units. **101.** 15900 units **103.** 125 gms.
104. 500 gms. **105.** 7·95 kg. **107.** 252·3 lbs.
109. 11·05 gms. **111.** 0·1108 **112.** 80.
113. 79·5 **115.** (*a*) 0·625 lb. of ice will melt;
(*b*) *Here in place of 8°C read 80°C*; all the ice will melt and the resulting temp. will be 26°·6C.

116. 16°·8C **117.** 67°C **119** 537·7.
120. 540. **121.** 8··4 gms. **123.** 86°·7C.
124. 48°90C. **125.** 7160 units. **128.** 0·099.
129. 0·699. **130.** 12·6 × 10⁶ J being 4·2 × 10⁷.
130. 4·4 × 10⁴.

CHAPTER IV. (pp. 42-57)

1. 10 ft **3.** 2·7 ft. **4.** 299,000 kilometers or 186,000 miles. **5.** 9401 miles app.

6. $4{\cdot}9 \times 10^{11}$ miles **7.** $3{\cdot}2 \times 10^{10}$ conds **9.** 15·1.
11. 40 cms. from the smaller if between the two or 120 cms. from it, if the lamps are on the same side.

12. *Here is a misprint—the latter portion should read thus—where must a screen be placed between them so as to be equally illuminated by each.* Between the two flames and 60 cms. from the 9 c.p. lamp ; 420 cm. beyond the lamp. **13.** 1·26 metres.
14 Distance from A, $66^2/_8$ cms ; **16.** ·79 cms.

17. 20 cms. **19** 120° **20.** 45°.
21. 60°. **22** (i) infinite no. of images. (ii) 35. (iii) 11. (iv) 7. (v) 5. (vi) 3 ; when the mirrors are parallel an infinite number of images are formed.

24. The image is 66·7 cms. behind the mirror and is virtual, enlarged and erect. **26** 48 cms.
28. (1) $u=2f$. (2) $u=5f$. **29** The image is at infinity and in dimension equivalent to a point.

33. Image is real and 0 26 cm. high. **34.** *Here is a misprint, for* 33 cms. *read* 28 cms. *and also for* 42 mm. *read* 4·2 ; The image is 15 5 cms away ; real, inverted, 2·3 m m broad and 7·7 m m. long **36** The image is 150/13 cms. away and is inverted and 3/13 times the object. **37.** Image is inverted, 4/3 cms. in size and —2 cms. from the object. **38** . 6 inches.

39. 2 in. behind the mirror. **41.** ·5 5/6 cms ; —8 3/4 cms. **42.** $u=3, f=18/7$. **43.** focal length 2·5 cms ; the mirror being concave.
46. 1·73. **49.** 30°. **51.** 9/7.

53. 1·7 app. **54.** 8/9. **56.** $1\frac{7}{8}$ in. nearer
58. 4·38 **59.** 1·3. **61.** $\sqrt{2}$.
64. $6\frac{2}{3}$ cms ; virtual. **65.** At infinity.

66. —24 cms. **67.** The image is real, inverted and twice the size of the object and distant 24 cms. from the lens.
68. Length of image=2 cms ; the image is virtual and erect.

69. Distance of image=—12 in. ; Length=4 in.
70. —72 cms. **71.** $2f$; $3f$; **73.** focal length= $3\frac{1}{3}$; convex. **74.** concave lens ; 200/17.

75. *Here, for* 1 mm. *read* 1 inch ; $f=24/11$ ft.
76. 10·9 ; concave. **77.** 80 cms.
79. 10 or 15 cms. from the wall. **80.** Convex lens, placed 64 cms. from the screen. **82.** —6 cms.

83. 24 cms. **84** $-\frac{1}{20}$; $\frac{1}{10}$. **85.** —3.
89. 21 4 cms. **91.** Concave spectacles of 6 in. focal length.

CHAPTER V. (pp. 58-64).

3. 1000 cms. per sec. **6.** 1680 yds. **8.** 38 sec. app. **10.** 448 ft. **11.** 1 : 4. **14.** 680. **15.** *Here is a misprint for $n=356$, read* $n=256$; 960. **16.** 512. **17.** 480. **19.** 369. **21.** 150. **23.** 33·3 cm.; 22·5 kilos. **25.** 280. **27.** 12 in. **28.** 449 ft. per sec.

CHAPTER VI. (pp. 65-66.)

2. Attractive and = ·48 dynes. **3.** 5. **4.** 125. **5.** 2 : 3. **6.** 122·625 **7.** unit intensity. **8.** 10.

CHAPTER VII. (pp. 76-72.)

2. 12 dynes. **6.** 0·14 dyne. **9** 7·08 app. **11.** Potential at D = 5·4 ; at O = 8·484 ; work = 3·07 ergs. **14.** 7·13. **15.** 1·6. **17.** Potential = 15 ; charges = 1125 and 375. **19.** 500. **22.** 4 cms. **24.** 7500 ergs.

CHAPTER VIII. (pp. 73-83.)

5. 2 ohms. **6.** 30 volts. **7.** The resistance of one is 81 times that of the other. **8.** 2 ohm. **10.** current = 1·2 amperes ; Potential diff. = 1·44 volts. **14.** 12·7 ohms. **15.** 150 ohms. **16.** ·99 ohms. **18.** 4·5 ohms ; ·4 amperes **19.** C : C′ = l′s : ls′. **22.** 108 units. **24.** 0·0754 dyne. **25.** $\sqrt{3}$ · 1. **26.** 1 : $\sqrt{3}$. **29.** 1·03 ohm. **33.** 14·15 gms. **34.** 6·16 amperes. **36.** 2·3 amperes. **38.** 28·1 ohms. **39.** 18·57 ohms. **40.** 25 cms. from one end.

UNIVERSITY PAPERS

WITH

ANSWERS

The Calcutta University
Intermediate Examination
Papers

ON

PHYSICS

FROM 1909 TO 191

WITH ANSWERS.

NOTE.

For the convenience of reference the subject-matter of each question has been shown on the MARGIN *on the right hand side. In cases where a question has been repeated in the University Papers of different years, the year, the paper and the question number of such repititions have also been put in the margin, from which it is hoped, the student will be able to realise the importance of a question from the University stand-point.*

For drawing GRAPHS *students are advised to provide themselves with square papers of the same size as are often supplied at the examination hall. Such a piece of paper generally contains 8 big divisions on one side and 10 on the other, each big division containing 10 smaller ones. It should be remembered that such numerical values must be assigned to a division on the square paper along each axis, such that the graph when drawn may fairly extend through the whole of the square paper. The nature of the graph may next be verified from those that have been inserted in this book. For directions on drawing graphs in Physics, see De's, Practical Physics, page 18.*

PHYSICS.

1909.

Paper-setters { MR. C. W. PEAKE. MR. R. S. TRIVEDI. DR. E. P. HARRISON.

FIRST PAPER.

Only SEVEN *questiones to be attempted, of which the tenth must be one. All the qustiones are of equal value.*

1. You are provided with a strip of plane mirror, some pins and drawing materials. How would you prove experimentally that the image of a fixed object remains in the same spot whatever may be the position of your eye ? **Reflection from Plain Mirror.**

2. What do you suppose to be the cause of the colour of an opaque object illuminated by white light ? **Colour of bodies 11-IA-3**

Why do ordinary blue and yellow pigments appear green when mixed ?

Objects which appear variously coloured in white light are illuminated by sodium flame. Describe and explain the effect observed.

3. Explain by means of diagrams, how the position and size of the image varies with the position of an object for a convex spherical mirror. **Convex mirror.**

An object of height 1 inch is placed at a distance of 3 ft. in front of a convex mirror or 4 feet radius. Find the position and the magnitude of its image.

4. A short-sighted man who can read clearly when the print is not more than 3 inches from his eye, requires spectacles to enable him to see a distant view. What kind of lens does he need and what must be their focal length ? Draw as accu- **Myopia.**

rately as you can, the path of a ray of light from a distant object through the lens of the man's eye (*a*) without the spectacles (*b*) with the spectacles.

Vapour pressure.

5. Two barometers stand side by side. A few drops of water are introduced into the vacuum of the one and a little air into the other. What would be the effects on the errors in the barometer readings thus produced of (*a*) a change in the atmospheric pressure (*b*) a change in the temperature ?

Pitch by Resonance Column of air. 11-1-6. 12-1-9. 14-1-9.

6. Assuming that the velocity of sound in air is known, describe in detail one method of measuring the vibration frequency of a tuning fork.

Loudness, 12-1-9. Quality. Use of Resonance box.

7. Describe the physical cause which gives rise to the sensation of loudness and of quality in a musical note. Why are the strings of such an instrument as the violin mounted upon a hollow wooden box ?

Sp. Gr. 13-1-3. 15-1-2.

8 Describe carefully any two methods of finding the specific gravity of a piece of glass.

Pendulum.

9. Two simple pendulums of length 1 metre and 1·1 metre respectively start swinging together with the same amplitude. Find the number of swings that will be executed by the longer pendulum before they are again swinging together. [g = 978 cms/sec.]

Graph

Vol. of water at diff. temp.

10. From the following data plot a curve showing the variations in the volume of a mass of water with the temperature. Find graphically two temperatures at which the volume of one cubic centimetre of water at 0° becomes equal to 0·99990 c.c.

Temperature	Volume	Temperature	Volume
0	1·000000	7	0·999952
1	0·999948	8	1·000003
2	0·999911	9	1·000068
3	0·999889	10	1·000147
4	0·999883	11	1·000239
5	0·999891	12	1·000344
6	0·999914	13	1·000462

SECOND PAPER, 1909.

Answer any TWO *out of questions 1, 2, and 3, and* FIVE *from the rest.*

1. What do you mean by the term Mechanical Equivalent of Heat?

An engine of 1 horse power is used in boring a block of iron of mass 1000 lb. Assuming the whole of the work done by the engine is used up in heating the mass of iron, calculate approximately the rise in the temperature of the iron after the engine has been working for 20 minutes. [The number of units of work required to raise the temperature of 1 lb. of water 1° Fahr.=772 foot lbs. The sp. heat of iron=0·1; 1 horse power=550 foot lb./sec.] **Mech. quivalent of heat**

2. A small solid metallic object is immersed in a beaker of water and suspended from the arm of a balance. What whould be the effect on its apparent weight as indicated by the balance of **Upward Press. in a liquid.**

(*a*) an increase in temperature of the water

(*b*) an increase in the temperature of the solid

(*c*) an equal decrease in the temperature of both water and solid?

3. What do you mean by the term Latent Heat of Fusion of a substance? **Lt. heat. of fusion.**

A limp of ice weighing 100 grammes is placed in a beaker containing a litre of water at a temperature of 52°C. When all the ice has melted the temperature of the water in the beaker is observed to fall to 40°C. Find the Latent Heat of ice, neglecting loss of heat by radiation and conduction.

4. State Faraday's laws of Electrolysis. **Laws of Electrolysis.**

0·4 gram of metallic copper is deposited in half an hour on the cathode of an electrolytic cell during the passage of a steady electric current. Find the value of the current and name the units

in which you express your result. Electrochemical equivalent of copper = 0·000326.

Electromagnetic induction.

11-IIB-4, 13-II-10, 14-II-9.

5. Two coaxial cylindrical coils of wire, insulated from one another, are arranged so that the outer one is connected to a galvanometer and the inner one to the terminals of a battery. Describe consecutively the behaviour of the galvanometer when the battery circuit is suddenly closed, left closed for two or three minutes, and then opened. When the battery circuit is open, describe exactly what is the effect of putting the north pole of a bar magnet into the middle of the inner coil.

Illustrate your descriptions by careful diagrams.

Metre-bridge.

6 Give the theory of Wheatstone's Bridge method of measuring a resistance. Draw a diagram of an ordinary metre-bridge and show clearly the various connections that have to be made in practice.

What is the effect observed if the galvanometer circuit is closed before the battery circuit?

Heating effect of a current.

7. A coil of wire of resistance 2 ohms is soldered to two thick copper rods and immersed in 1000 grams of oil (sp. heat of oil 0 6). A current of strength 3 amperes is passed for 30 minutes. Neglecting the water-equivalent of the calorimeter, loss of heat by radiation etc., find the rise in temperature of the water. A current of 1 ampere passing through a resistance of 1 ohm for 1 sec. generates 0·2387 calories.

Mag. lines of force.

8. Describe what is meant by a line of force of a magnet. Two bar magnets are placed end-to end with the North poles towards one another separated by few millimetres, Draw the lines of force in the plane of the paper, neglecting the effect of the earth's field.

What would be the effect on the magnetic field of placing a small ring of soft iron (with its plane parallel to the plane of the paper) in the space between the two north poles?

9 The poles of a bar magnet are not necessarily on the axis of symmetry of the magnet. How would you find experimentally the direction of its magnetic axis? **Mag. axis of a magnet.**

10. A strip of copper and a strip of zinc are dipped into a vessel containing dilute sulphuric acid. The strips are attached to the two terminals of a galvanometer the needle of which is observed to be deflected. This deflection decreases considerably after the strips have remained for some time in the acid. Why is this? What methods have been adopted in practice to avoid this effect in voltaic cells? Give examples. **Defects of a simple cell and their remedies.**

ANSWERS.

FIRST PAPER—1909.

1. The image of a fixed object in front of a plane mirror seems to be formed at a fixed point behind the mirror; hence from whatever position of the eye it is looked at, it remains at the same spot.

To locate the position practically, we should proceed in the following way (*See De'-Practical Physics, page 163*).

2. When white light is incident on an object, a portion of light is absorbed and is frequently converted into heat, a second portion is reflected while a third is transmitted. The colour of opaque bodies is due to the reflected light, while a transparent body has its colour determined by the transmitted light.

Blue pigment absorbs all the components of white light except the indigo, blue and green (the first and the last being adjacent colours are not absorbed). Similarly, the yellow pigment absorbs all except the green indigo and red. Thus a mixture of the two appears green, for it is the only portion, that is not absorbed by either.

Thus a body is of red colour because red is the predominant colour in the light reflected from the surface of the body. The presence of other colours in the reflected light will determine the so-called 'shade' of red.

Objects coloured other than yellow in the ordinary day light when brought under the yellow light of a sodium flame appear black, because the yellow rays are all absorbed by the body and there is no other ray to be either reflected or trasmitted by the body which determines the colour of a body, opaque or transparent. Objects coloured yellow, will appear very bright because the yellow rays are not absorbed but reflected or transmitted, as the case may be. (*See Glazebrook—Art. 125; also Ganot—Art. 380.*)

3. For a convex mirror the image is always virtual, erect, smaller than the object and on the side of the mirror remote from the object. When the object is at infinity, the image is on the focus and is almost a point in size. As the object approaches the mirror, the image moves from the focus to the mirror increasing in size from a point to that of the object itself.

The following two figures will illustrate the point. (Here draw a fig. after *fig. 69 Glazebrook.—Light.* Next draw another to show the position and size of the image when the object PQ is taken nearer. Show that the image has grown bigger and has approached the mirror).

In the example given, $u=3$ ft. $r=-4$ ft., $\therefore f=r/2=-2$ ft.

Substituting in the usual equation

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}.$$

We get $$\frac{1}{v}+\frac{1}{3}=-\frac{1}{2}.$$

Whence $$v=-6/5 \text{ ft.}$$

Thus the image is virtual and is formed behind the mirror.

Again the magnitude of the image is given by

$$\frac{\text{Height of image}}{\text{Height of object}}=\frac{v}{u}. \quad \text{or} \quad \frac{1}{1\,in}=\frac{6/5}{3}$$

Therefore the image is 2/5 in. long.

4. A short-sighted eye cannot focus for a distant object; in other words, a pencil of parallel rays is made to converge by the human lens at a point not on the retina but a little in front of it,—the lens being too much convergent To focus the parallel rays at a point on the yellow-spot, a little divergence should be introduced before the rays pass through the human lens; this can be secured by the use of an auxilliary *concave* lens in front of the human lens,

The function of the concave lens will be to produce an image of a very distant object (the rays from which may be consi-

-dered parallel) at a point 3 in, in front of the eye. so that the eye can then focus for it. In other words, the concave lens must have a focal length of 3 in. Objects at nearer distances will have their images within 3 in. ; thus all objects will be seen.

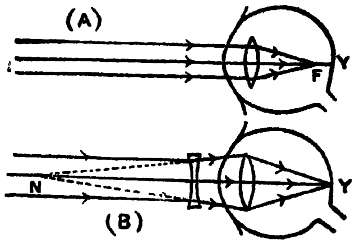


FIG. (A) A MYOPIC EYE WITHOUT SPECTACLES.
FIG. (B) " " WITH "

Fig. (A) shows the path of light from a distant object, passing through the eye without spectacles ; fig. (B), with the spectacles on.

5. The barometer containing air :—

(a) Changes in atmospheric pressure will produce smaller variations in the height of a barometric column than in the case of a true barometer, on account of the elasticity of air in the faulty barometer.

(b) When the temp. is diminished, the height of the column will increase as the volume occupied by the air above the mercury level will diminish. With rise of temp. the gas expands in volume, its pressure also increases and the result is that the column of mercury is forced down.

The barometer containing water :—Here we have to consider two cases viz.,

(1) When the space above the mercury column is unsaturated.

(2) When it is saturated with water-vapour.

In the first case, it will behave like a gas and the observation will be as in the previous case.

When the space above is saturated, (a) changes of atmospheric pressure will be correctly shown, since the pressure of aqueous vapour is constant. The pressure of saturated aqueous vapour,

so long as temp remains constant, is constant and is obtained from the difference in height of the mercury column in the correct barometer and that in the faulty barometer.

(*b*) A rise of temp. would reduce the mercury column, for, in that case pressure of aqueous vapour increases; while, a fall of temp. would increase the column.

6. We can determine the frequency n of a fork from the relation

Velocity = frequency × wave length.

To find the wave length in air of the note emitted by the fork we arrange to have a resonant column of air corresponding to the note.

(For the practical portion see *De's Sound. Art 35*, and for the application of the formula see *Art 75*).

7. For Loudness - *See De-Sound, Art 47* (*ii*)

„ Quality— „ *Arts 43, 66* last para.

For the second part of the question—See *De' Art 33* (*vi*)

8. (*a*) Hydrostatic Balance method, *See De' Prac. Physics. p.* 100.

(*b*) Nicholson Hydrometer—See *Practial Physics pp. 102-4.*

9. The period of oscillation in the case of the shorter pendulum

$$t_1 = 2\pi\sqrt{\frac{100}{g}}.$$

For the longer one

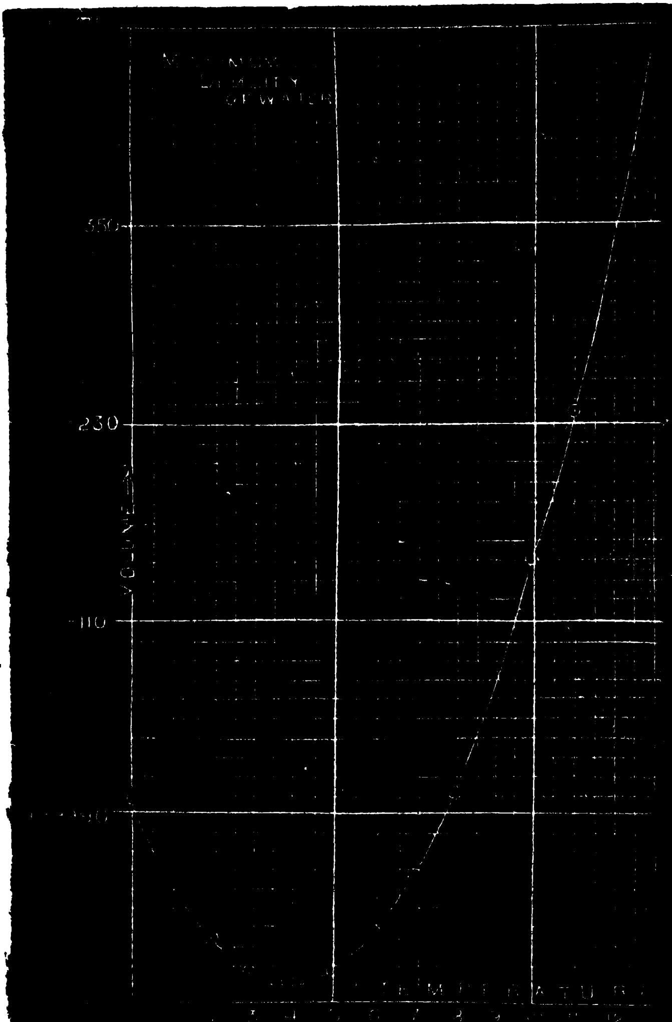
$$t_2 = 2\pi\sqrt{\frac{110}{g}}.$$

Let the two pendulums start swinging together. Now, when the longer one has finished the first oscillation, it has taken $t_2 - t_1$ seconds more than the shorter pendulum.

Let n be the no. of swings of the larger pendulum after which both swing together again. When this occurs, $n(t_2 - t_1)$ must be equal to t_2 or a multiple of t_2.

Let $n(t_2 - t_1) = A \times t_2$, where A is any integer.

Or $$n = \frac{A\,t_2}{(t_2 - t_1)} = A.\frac{\sqrt{110}}{\sqrt{110} - \sqrt{100}}$$



VARIATION OF DENSITY OF WATER
WITH TEMPERATURE.

$$= A\ \frac{\sqrt{110}(\sqrt{110}+\sqrt{100})}{10}$$

$$= A\ \frac{110+10\sqrt{110}}{10}$$

$$= A\ (11+\sqrt{110})$$

$$= A \times 21{\cdot}2 = \frac{106}{5} \cdot A.$$

Therefore, to get a whole number for the value of n, the least value of A must be 5

N. B —This is not a fair question for an I. Sc. Paper. In fact, the closer is the approximation taken in finding the roots of the irrational quantity, the value of n would go higher. Strictly speaking, the correct answer would be infinity.

10. From the graph in the opposite page the reqd. temperatures are $2^\circ{\cdot}41$ and $5^\circ{\cdot}4$C. when the volume is 0 9999c.c.

Here y axis represents the volume in c.c.

1 big division ,,=0 000120, so 1 small div.='000012

And x axis represents temperature in centigrades

2 small divisions $=1^\circ$C.

SECOND PAPER.—1909.

1. For the meaning of the term Mechanical Equivalent of heat see *page 40 of this book*.

In the example given

Heat generated by the engine in 20 minutes

$= $ work done by the engine $\times \frac{1}{772}$

$$= \frac{550 \times 20 \times 60}{772}$$

$= 854{\cdot}7$ units (taking the heat reqd. to raise the temp. of 1 lb. of water through 1° F as the unit of heat.)

Now heat generated by the engine

= Heat absorbed by the iron

$= 1000 \times 0{\cdot}1 \times t$

i.e. $854{\cdot}7 = 100\, t$ whence $t = 8^{\circ}{\cdot}547$ F

2. From Archimedes' Principle we know that a body immersed in liquid loses a part of its weight equal to the weight of the displaced liquid.

(*a*) When the temp. of the water increases, its density decreases, hence the weight of the displaced liquid being less than before, the body appears heavier.

(*b*) As the temp. of the solid only increases, it expands in volume and displaces more liquid than before, thus appearing lighter.

(*c*) For an equal decrease in temp. of both water and the solid, the following changes occur,—(1) the volume of the body diminishes (2) the density of the water increases. But as liquids contract more than solids (their co-efficient of expansion or contraction being greater), the weight of a volume of water equal to that of the solid is greater than before and the body thus losing greater weight appears lighter.

3. For Latent Heat of Fusion of a substance—See *Glazebrook Art 112* (4).

In the example given,

Heat gained by 100 gms. of ice in rising from 0°C to 40°C.

$= L \times 100 + 100\,(40-0)$

$= 4000 + 100\, L$ units

Again, heat given out by 1 litre of water at 52°C in falling to 40°C $= 1000\,(52-40)$

= 12,000 units

Now Heat given out by water = Heat absorbed by ice

i.e. $12000 = 4000 + 100\,L$ whence $L = 80$.

4. For Faraday's Laws—See *Poyser—Advanced Mag. and Elect. Page 270.*

From Faraday's Laws, we have

$W = Czt$ See *page 82 of this book*

Here $W = 0{\cdot}4$ gm. $z = 0{\cdot}000326$ and $t = 30 \times 60$ seconds.

Thus $0{\cdot}4 = C \times 0{\cdot}000326 \times 1800$

whence $C = {\cdot}68$ ampere

5. For the diagram—See *Poyser. Fig. 248, page 285.*

For the effects of the current and the magnet—See the excellent table given in *Poyser. page 286.*

6. For the theory of Wheatstone bridge—See *De' Practical Physics Page 270-71.* For the diagram of a metre-bridge and its arrangement see *page 272 as above.*

If there is inductance in the circuit there will be a sudden big throw of the galvanometer which may disturb the adjustment.

7. In the question there is a misprint, read oil for water.

Here, we have that a current of 1 amp. through a resistance of 1 ohm. and acting for one second generates 0·2387 calories.

And, we know that H, the heat generated is proportional to C^2.

$$\therefore \text{ Here } H = 3 \times 3 \times 2 \times 30 \times 60 \times 0{\cdot}2387$$
$$= 7733{\cdot}88 \text{ calories.}$$

This quantity of heat has been absorbed by 1000 gms. of oil of specific heat 0·6 and its rise of temp. t is given by

$$1000 \times 0{\cdot}5 \times t = 7733{\cdot}88$$
$$\text{whence} \quad t = 12^\circ 9 \text{ C.}$$

8. See *Practical Physics, page 208.*

The lines of force will be like those shown in *fig.* 29 *Poyser, page 22,*

For the effect of a soft iron ring, *See fig.* 33, *Poyser.*

9. In determining the magnetic axis it is to be remembered that the latter is always parallel to the magnetic meridian and a freely suspended magnet always rests in the magnetic meridian.

To find the magnetic axis, fix two pieces of card-board, one on each of the bar-magnet. These card-board pieces should have a hole each to which a vertical cross-wire is attached. Now let the magnet be freely suspended over the drawing board when it will be found to rest parallel to the magnetic meridian and the cross-wires will seem to coincide, when looking through the hole nearest the eye. Now fix two pins on the paper so that these two and the cross-wires appear to lie on the same straight line. Draw a st. line joining the pins. Again, turn the magnet upside down and obtain another straight

line in the same way. It will be found that these lines intersect, and the line bisecting them will give the magnetic axis of the bar-magnet.

10. The current in the cell may stop owing to the following causes :

1. Neutralisation of the acid—which may be remedied by replacing the acid.

2. By Local Action—which may be remedied by the amalgamation of the zinc plate—See *Poyser page* 190.

3. Polarisation—which may be remedied by the following means .—

(1) Mechanical—by brushing the plate from time to time and making the surface of the plate rough.

(2) Chemical—by using a second liquid in the cell which will oxidise the hydrogen bubbles.—See *Poyser, page* 191.

(3) Electro-chemical—by using a porous pot within a cell and arranging matters such that some solid metal such as copper shall be deposited on the cathode instead of hydrogen bubbles.

1910.

FIRST PAPER.

Paper-setters. { DR. E. P. HARRISON. MR. BRUHL. MR. K. K. BANERJI.

Six *questions are to be attempted, of which question* **10** *must be one.*

To show g is const at the same place.

1. Describe in detail how you would test by means of pendulum experiments whether the acceleration due to gravity is the same for all substances.

Sp. Gr. of a cork.

2. A prism of cork, 16 cms. high, and of square section equal to 2 cms. side is cemented to a prism of lead of the same cross section and 1 cm. high. The composite prism is allowed to float in water. How much of it will project above the surface of the water? [Specific gravity of cork, 0·25, specific gravity of lead, 11.]

Pressure in a liquid.

3. Define 'intensity of pressure at a point in a fluid.' Prove that the difference of pressure between the surface of a liquid and a point in the liquid z cms. below the surface is given by $p=gdz$, where d is the density of the liquid, and g is the acceleration due to gravity.

A U tube, open at one end and closed at the other, is partially filled with mercury (density 13·6). The closed end of the tube contains some air, and the mercury in the open limb stands 30 cms. higher than it does in the closed limb. Find in C. G. S. units, the intensity of pressure on the air in the closed end of the tube.

Mech. Equivalent of heat '09-1-1.

4. A cylindrical tube made of non-conducting material and closed at both ends contains 500 grams of lead shot which, when the tube is held vertically, occupy 6 cms. of the tube length. The tube is suddenly inverted so that the end originally above is now below,

and the shots fall to the other end of the tube. The tube is then again quickly inverted, and this process is repeated 200 times. At the end of this process the temperature of the shot is found, by means of a thermometer, to be 1·4°C higher than it was at the beginning of the experiment. Find the value of the mechanical equivalent of heat. (Specific heat of lead, ·03. It is assumed that no heat is lost by radiation and conduction.)

5. Describe an experiment which illustrates the refraction of radiant heat. Be very careful to explain what you would use as your source of radiant heat and how you would detect the refracted beam. **Refraction of Radiant heat.**

6. Distinguish carefully between saturated and unsaturated vapours.

Into a cylinder exhausted of air and provided with a piston there is introduced just enough water to saturate the space at 20°C. Describe what happens under the following conditions — **Saturated and unsaturated Vapour.**

(a) The volume of the space is increased by pulling out the piston.

(b) The volume is diminished by pushing the piston down.

(c) The volume remaining as at first, the temperature is increased to 30°C.

(d) The temperature falls to 10°C.

7. Describe some simple form of syren. **Syren.**

The disc of a given syren has 32 holes. A tuning-fork makes 512 vibrations per second. What must be the speed of rotation per minute of the syren disc so that the note emitted by the syren may be in unison with that emitted by the tuning fork?

8. Explain what you mean by amplitude of vibration, and velocity of propagation, in the case of a longitudinal wave. **Amp. of vibration**

When are two vibrating particles said to have the same phase? **Phase**

What are stationary waves? How are stationary waves produced in the case of a 'stopped' organ pipe? **Stationary waves.**

α for glass.

9. A long glass tube of uniform capillary bore contains a thread of mercury which at 0° is 1 metre long. At 100°C. it is 16·5 mm. longer. If the average coefficient of volume expansion of mercury is ·000182, what is the coefficient of linear expansion of glass?

Graph.

Verification of Boyle's Law.

10. In an experiment which had the verification of Boyle's law for its object the following data were obtained :—

Pressure in millimetres of mercury :—

230	410	580	760	850	930	1010

Volume in cubic centimetres .—

167	102	73	55	49·2	45	41·4

Draw a curve representing the relation between volume and pressure at the given steady temperature.

SECOND PAPER.

Answer any TWO *out of the first four and* FIVE *from the rest.*

Deviation by a Prism.

1. Explain how, by means of pins and a large glass prism, you could obtain the relation between the deviation of a pencil of light and its angle of incidence on the prism face. Draw a curve showing the kind of graph you would expect to obtain, and briefly discuss the meaning of the graph.

Photometry

2. You are given a drawing board, a sheet of white paper, a lead pencil, and a metre tape. Making use of these articles, how would you compare the candle power of two kerosene oil lamps of different patterns? Supposing that the candle powers of the two lamps are found to be 25 and 40 respectively, what were their relative distances from the screen?

Pure spectrum

11-11A-4.
13-11-2.
14-11-4.

3. You are asked to produce a pure spectum of sun-light. For what apparatus would you ask? Describe in detail how you would arrange the apparatus? Suppose that (*a*) a flame of Bunsen burner coloured by sodium chloride (*b*) a vacuum tube cotaining hydrogen and made luminous by means of an electric discharge were used instead of the sun as a source of light, describe in general terms the spectra produced.

4. Draw figures, approximately to scale showing the paths of the light rays and the positions of the images formed when a luminous object (say an arrow) is placed at a distance (*a*) of 1 inch (*b*) of 6 inches from a convex lens of 2 Inches focal length. **Image by Convex lens.**

5. State the law of Ohm. If you were given a resistance box, a tangent galvanometer and an accumulator cell of small internal resistance, also copper wire etc., how would you test the truth of the above law experimentally? **Ohm's Law. II-IIB-3.**

6. You are given an insulated charged body. A, a hollow insulated conducting body B, and a larger hollow insulated conductor C. The vessel B can be placed entirely inside C without touching it. Show how it is possible to give to C any multiple of the charge on A without bringing A into contact with anything. **Electro-static Induction**

7. How would you prove the law of inverse squares for magnetic forces, given (*a*) a magnetised rod of steel about a metre long (*b*) a small suspended magnetic needle, (*c*) a measuring rod and (*d*) a stop watch? **Proof of mag Law of Inverse squares.**

8. You have at your disposal (*a*) three Daniell's cells (*b*) a beaker (*c*) some platinum foil (*d*) some thin sheet of copper (*e*) a litre of dilute sulphuric acid, (*f*) insulated copper wire, (*g*) clamps &c. Draw a diagram showing how you would arrange matters for the purpose of studying the electrolytic effect of the cells, if one, two, or all the cells are joined up in series. What different results would you obtain in the three cases? **Electrolysis**

9. Describe what you observe when a discharge from an influence machine is passed between two smooth metallic balls placed at varying distances from each other. What difference is produced in the appearance of the spark by placing a capacity in parallel with the spark-gap? State your ideas as to the mechanical process involved in the passage of the spark. **Electric discharge as sparks**

10. A current is flowing in a straight wire four meters long. You are given a magnetised steel needle about one cm. long suspended by means of a silk fibre. How would you prove experimentally that the strength of the magnetic field due to the current falls off as the distance from the wire increases? **Mag. force due to a current.**

ANSWERS.

FIRST PAPER, 1910.

1. The period of oscillation t of a simple pennulum is given by

$$t=2\pi\sqrt{\frac{l}{g}}$$

where l = length of the pendulnm measured from the point of oscillation to the point of suspension (The pt. of oscillation is very nearly the centre of gravity of the pend.) and g=the acceleration due to gravity.

Take spheres of diff. substances, say, lead, copper, ivory etc. and suspend each in turn by a string, so that the length l which is equal to the length of the string + the radius of the ball) is the same in each case. The radius r is obtained from the mean of several measurements of the diameter of the spheres, taken by a slide-calipers.

Note the time taken for some 20 oscillations and hence find t; it will be observed that neglecting the resistance of the air the pendulums oscillate in equal times, thus showing that the acceleration due to gravity is the same for all substances at the same place.

2. We know that a body floating in water displaces a quantity of water equal to its own weight.

Here volume of the cork $=2\times2\times16=64$ cc.

" " lead $=2\times2\times1 = 4$ cc.

$\therefore$ wt. of cork $=64\times0{\cdot}25=16$ gms.

" " lead $=4\times11 =44$ gms.

Total wt. $=44+16 =60$ gms.

Let h be the length of the composite prism within the water.

Then, vol. of water displaced $=2\times2\times h$ cc.

$\therefore$ wt. of displaced water $=2\times2\times h$ gms.

which must be $=60$ gms.

$\therefore$ $2\times2\times h =60$ gms. whence $h=15$ cms

$\therefore$ the length out of water $=(16-15)=1$ cm.

3. Intensity of pressure *at a point* in the fluid is the pressure on unit area round the point, supposing the pressure is uniform on the surface of the fluid.

Press. at a pt. A within the liquid

= Diff. of press. at the liquid surface and at A

= press. on a unit area round A

= wt. of a column of liquid standing on the unit area and reaching the liquid surface

$= mg$ where m is the mass of the liquid

$= vdg$ where v is the vol and d, the density of the liquid.

$= gdz$ for $v = z \times 1$

But vol. of liquid in the column

= height of the liquid $\times$ its cross-section

Again, press. on the surface of the liquid $= \pi$

where π is the atmospheric pressure.

$\therefore$ Total press at $A = \pi + gdz$

So that the diff. in press. at $A = gdz$.

Draw a fig. of the U–tube and show the heads of the liquid columns in it.

Press. of air in the closed limb.

= atmos. press. + that due to a column of 30 cms. mercury

As the atmos. press. and g are not given here we may take their normal values, namely, that due to 76 cms. of mercury and 981 dynes respectively

$\therefore$ Press. of air = that due to $(76+30)$ or 106 cms. of mercury

$= 106 \times 13{\cdot}6 \times 981$ dynes $= 1{\cdot}4 \times 10^6$ dynes.

4. Here, mass of lead $= 500$ gms.

No. of times the tube is inverted $= 200$

Dist. in cms. the shot falls $= (l - 6)$ cms. l being the length of tube.

Rise in temp. $= 1^\circ{\cdot}4$C.

Sp. heat of lead $= 0{\cdot}03$.

$\therefore$ The work done by gravity $= 200 \times 500 \times l$ gm.cms.units

Heat gained by lead $= 500 \times 0.03 \times 1.4$ units

$\therefore$ Mech. Equivalent, J $= \dfrac{\text{Work done}}{\text{Heat gained}}$

$$= \frac{200 \times 500 \times (l-6)}{500 \times 0.03 \times 1.4}$$

$$= 4762 \times (l-6) \text{ gm.cms.units}$$

In the example l, the length of the tube is not given. Taking the value of $J = 4.2 \times 10^4$ gm. cms. units the intended value of l is about 15 cms.

5. An excellent answer to the point is given in *Glasebrook, Heat, Art 160 (i) and (ii), Experiment. 50 (a) and (b).*

6. For distinction between saturated and unsaturated vapour see *pages 124 and 131-32 Glasebrook, Heat.* State the effects or changes of temp. and pressure on saturated vapour (*page 124*) and on unsaturated vapour (*pages 131 32 ibid*).

For the second part of the question :—

(*a*) The vapour becomes unsaturated. as the volume of the space which is now increased, can hold more vapour.

(*b*) When the volume is decreased, there is more vapour than would saturate the space, therefore some vapour is condensed.

(*c*) The temp. having increased the saturation pressure increases but as there is no more liquid to vaporise, the space becomes unsaturated.

(*d*) Some vapour is condensed while the space remains saturated with the saturation pressure at 10°C.

7. For the figure and description of the syren, see *De, Sound, Art 54. page 75.*

Now frequency of the fork

=frequency of the note from syren, when in unison.

=No. of holes in the syren disc × no. of revolution per sec.

or $512 = 32 \times n$ $\therefore$ $n = 16$ time per second

$= 960$ „ „ minute.

8. In the case of a longitudinal wave such as a sound wave the displacements of a particle in the medium through which the wave is passing, take place along the direction of propagation of

the wave. In other words, the particle moves to-and-fro about its mean position, its motion being of the type of a Simple Harmonic Motion.

The maximum displacement of a vibrating particle on either side of its mean position is called the *amplitude* of virbration.

The velocity of propagation of a wave is measured by the distance traversed over by the wave in one second. If λ be the wave-length *i.e.* the space passed over in the time of one period (T) of the vibrating sonorous body, then

$$v = \frac{\lambda}{T}$$

Two particles are said to be in the same phase when they vibrate in exactly the same way, *i.e.* with the same period and amplitude they pass the *corresponding points* in their paths at the same instant. [*De*, *Sound Art* 13. (*b*)]

When a region of a medium is affected simultaneously by two similar waves *i. e.* of the same period and amplitude, travelling in opposite directions along the same line, it is thrown into a state of vibration, known as stationary vibration Places of no motion (*i.e.* nodes) and those of maximum vibrations (*i. e.* anti nodes) become permanent or stationary in position.

The displacement at each point is in a fixed relation with respect to that of any other point. Unlike a progressive wave every particle has not to pass through a cycle of displacements. Hence in a stationary vibration there is apparently no transmission of vibratory motion from particle to particle.

In a stopped organ-pipe, the incident wave and its reflection from the closed end interfere with each other and give rise to a stationary undulation. The position of nodes and antinodes within the pipe can be experimentally investigated.

N. B. The explanation of the formation of stationary waves is outside the syllabus of the Intermediate Course in Physics ; hence a detailed answer has not been given.

9. Expansion of 1 metre or 1000 m.m. of mercury in length for rise of temp through 100 °C is through 16·5 m. m. in length.

∴ Co-efft. of relative expansion of mercury

$$= \frac{16{\cdot}5}{1000 \times 100} = 0{\cdot}000\ 165.$$

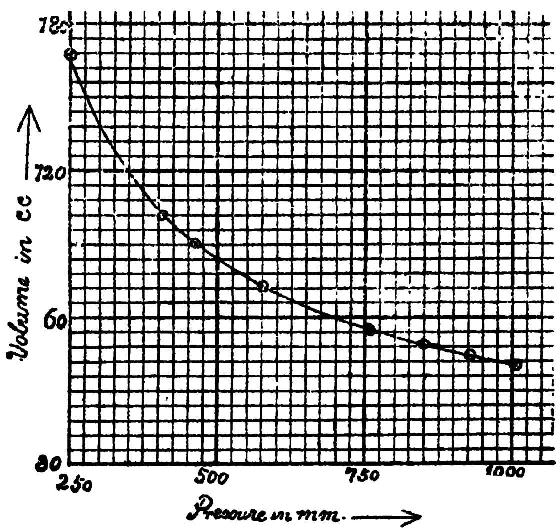
But the co-efft. of absolute expansion of mercury
$=0{\cdot}000182$.

Therefore co-efft. of volume expansion of glass

$={\cdot}000182-{\cdot}000165={\cdot}000017$.

Hence co-offt. of linear expansion of glass
$={\cdot}000017/3=0{\cdot}0000056$ nearly.

10. In tbe graph shown below



X axis represents pressure in m.m. of mercury

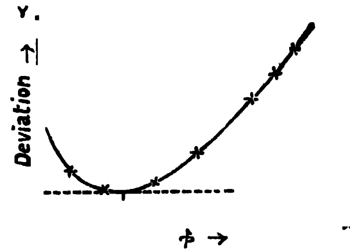
1 small div = 25 m.m.

and Y axis represents volume in c.c.

1 small div = 3 c.c.

SECOND PAPER, 1910.

1. For the practical portion see *De, Prac-Physics fig. 197.* The nature of the graph is shown in the adjoining figure, where the Y-axis represents the deviations corresponding to the angles of incidence represented along the X-axis. The graph shows that the deviation has a minimum value for a certain angle of incidence marked by an arrow in the figure.



For any smaller and larger angle of incidence the deviation will be greater.

2. With the apparatus supplied we can arrange a Rumford's Photometer. The pencil, held vertically in front of the board on which the sheet of white paper is gummed, can serve for the rod. Two shadows of the rod will be cast on the board due to the two lamps in front.

Adjust the distances of the lamps so that the two shadows appear to be equally dark ; this occurs when the intensity of illumination on the screen due to each luminous source is the same. Next *See De. Prac. Physics, Page 156.*

In the example, the squares of the distances must be proportional to the candle powers.

$$i.e. \quad \frac{25}{40} = \frac{d_1^2}{d_2^2}$$

$$\text{or} \quad d_1 : d_2 = 5 : 6{\cdot}33$$

3. For production of a pure spectrum see *De. Prac. Physics page 192.* For discussion on the purity of the spectrum so obtained, see *Glazebrook-Heat. page 186, Art. 111.*

For the second part of the question :—

(*a*) In this case only a bright yellow light is seen. This occurs in the yellow part of the spectrum of white light.

(*b*) In this case bright lines, characteristic of Hydrogen are observed. Two are very prominent, one occurring in the red part and another in the green part of the solar spectrum. A third line, fainter than the other two, is also seen in the blue part of the spectrum.

4. (*a*) The case is that of an object lying within the focal length of a convex lens.

Draw a figure after *fig.* 95, *Glazebrook, Light, page* 124 taking AF=2 in. and AQ=1 in.

The image is virtual, erect and is formed on the same side of the object. (*i. e., v is positive.*)

Show by actual measurement, from the diagram you have drawn, that the image distance=2 in. from the lens.

(*b*) This is the case of an object lying beyond twice the focal length of the lens. Draw a figure, *after fig.* 94, *Glazebrook.–Light, page* 193.

The image is real, inverted and smaller than the object. Show from your diagram that the image is formed at a distance – 3 in. from the lens.

5. For Ohm's law, see *Poyser. Page* 204. Note that the law of Ohm is not only true for the whole circuit but also for a part of the circuit. Thus, if e represents the difference of potential between the two ends of a conductor of resistance r, we have $C=e/r$.

For the answer to the second part of the question see *De' Practical Physics, Page* 268, *Method I or II.* A diagram of the arrangement should be given.

6. Suppose A has a charge $+q$. Bring B near to A and touch the former for a moment; of the charges induced in B, the part $+q$ passes to the earth and $-q$ remains on it. Now bring B inside C and let B and C touch each other; then B is discharged while the charge $-q$ resides on C. By repeating the above process any multiple of the charge on A may be given to C.

7. It can be proved theoretically that when a small magnetic needle, suspended horizontally, is made to swing under a magnetic force,

$$\text{the force} \propto \frac{1}{T^2}$$

where T is the period of oscillation of the needle.

First, let the needle oscillate under the earth's horizontal field H. Observe with a stop-watch the time taken by the needle to complete some 50 oscillations; hence find T, the time of one oscillation. We have

$$H \propto \frac{1}{T^2}$$

Now place the long, magnetised rod of steel to the north of the needle with its axis in line with that of the swinging needle

and with its S-seeking pole pointing towards the needle and at a distance d from it, so that it helps the Earth's field in bringing the needle back to the magnetic meridian, when it is displaced from that position. Determine T_1, the new period of oscillation as before. We have

$$H+F_1 \quad \propto \quad \frac{1}{T_1^2}$$

Increase the distance d_1 to d_2 and find again the new period of oscillation T_2. We have

$$H+F_2 \quad \propto \quad \frac{1}{T_2^2}$$

From the above, eliminating H, we get

$$\frac{F_1}{F_2}=\left(\frac{1}{T_1^2}-\frac{1}{T^2}\right)\Big/\left(\frac{1}{T_2^2}-\frac{1}{T^2}\right).$$

Again, on substituting the numerical values of T, T_1 and T_2 it is found that the right-hand expression is equal to $(d_2/d_1)^2$

$$\therefore \frac{F_1}{F_2}=\frac{d_2^2}{d_1^2}.$$

In other words, the law of Inverse Squares is true.

8. Support by clamps the platinum foil on one side and a thin copper sheet on the other within the beaker. Pour a quantity of dilute sulphuric acid in it. Connect the sheet by insulated copper wires to the two poles of the battery formed of *two* or *three* Daniell cells in series, the platinum being the anode. Draw a diagram (*See fig.* 232. *Poyser, Page* 263).

When a current decomposes an electrolyte, it performs a certain quantity of work; this work is expended in decomposing the electrolyte and in opposing the tendency of the liberated ions to recombine.

The liberated ions set up a current within the electrolytic cell in a direction opposite to that of the current from the cell. It has been calculated that the electro-motive force of this opposing current is 1·49 volts in the case of electrolysis of water, which is really the case here.

The *E. M. F.* of a Daniell cell is also calculated from the consideration of the energy due to the chemical action going on in the cell; this has been calculated to be 1.129 volts.

From the above result we learn that the *E. M. F.* of a single Daniell cell is insufficient to decompose water.

In practice, the cell would first send a current through the electrolyte but the current soon drops down and electrolytic action ceases.

With two or three cells the electrolytic action would continue to go on, for the *E. M. F.* of the electrolysing current is $2 \times 1{\cdot}129$ or $3 \times 1{\cdot}129$ which is higher than $1{\cdot}49$ volts. (See *Poyser, page* 226.)

N. B.—This is not a fair question for an Intermediate Paper Further the question is ambiguous.

9. When an electric machine is worked, small, straight sparks are seen to pass in quick succession between the discharging balls when these are close to each other. As the distance between the balls is increased, the sparks diminish in frequency, become elongated and zig-zag in appearance. When the distance is still further increased, the sparks cease to occur altogether.

By placing a capacity in parallel with the spark-gap a bigger charge will be necessary for the potential to be raised sufficiently high for the discharge. Hence the charge accumulates before the discharge takes place, the discharge spark being much more powerful than in an ordinary case.

The mechanical process involved in the passage of the spark may be stated thus: the tendency to recombine of the two opposite charges increases with their potential difference and when it becomes so great that the air, which is an insulator, can no longer resist their combination, the insulation is broken through and a spark passes which tends to equalise the potential.

10. This question is similar to *Q.* 7, *above*, only the magnetised rod of steel is here substituted for the straight wire, 4 metres long.

The wire is placed vertically and, the magnetic needle is placed at varying distances d_1, d_2 etc. from it on its east side. Then as before we have.

$$\frac{F_1}{F_2} = \left(\frac{1}{T_1^2} - \frac{1}{T^2}\right) \Big/ \left(\frac{1}{T_2^2} - \frac{1}{T^2}\right)$$

The right hand side, however, is practically shown to be equal to d_2/d_1.

$$F_1 \; : \frac{d_2}{d_1}$$

i. e. the strength of the magnetic field due to the current falls off as the distance from the wire increases.

1911

FIRST PAPER.

Paper setters { DR. D. N. MULLICK. MR. C. W. PEAKE. MR. R. S. TRIVEDI. }

Only SEVEN *questions are to be attempted.*

GROUP A.

1. State the principle of conservation of energy and give an illustration. **Conservation of Energy.**

A railway train is moving with uniform speed (*a*) on a level country, (*b*) up-hill. Explain how the energy supplied by burning coal in the engine is being expended in the two cases. **12-1-4 13-1-1.**

2. Describe experiments to show that water exerts pressure in all directions. **Pressure in a liquid.**

A plate 10 metres square is placed horizontally 1 metre below the surface of water, when the height of the mercury in barometer is 760 millimetres. What will be the total pressure on the plate ? (The density of mercury = 13·6.) **14-1-2.**

3. If you were given a piece of wood cut in the form of a cube, how would you very roughly determine its specific gravity without using a balance ? **Sp. Gr. without a balance.**

A Nicholson's hydrometer weighs 200 grammes and requires 50 grammes in the upper pan to sink it to the fixed mark ; what weight must be added to or subtracted from the weights in the upper pan to bring it to the fixed mark, when it is placed in a liquid of specific gravity 1·2 ?

4. State Boyle's law and describe experiments made to verify it. **Boyle's Law**

A faulty barometer contains some air which occupies 10 c.c. If it stands at 740 m.m., when a true **13-1-4, 15-1-4.**

barometer indicates a pressure of 750 mm., find the volume, the air will occupy at the standard pressure 760 mm.

Graph

5. The mean coefficient of expansion of mercury between 0°C., and t°C is a and the following table gives corresponding values of a and t.

t	a
0	0·00018179.
100	0·00018216.
150	0·00018261.
200	0·00018323.
250	0·00018403.
300	0·00018500.

Plot a curve to illustrate the relation between a and t and find from your curve the value of a at 220°C.

Pitch by Resonance column '09-1-6 '12-1-9 '14-1-1

6. Indicate what goes on in the body emitting a musical note and the medium which transmits it.

You are given a tall jar, the requisite quantity of water, and a tuning-fork. Describe how you will fiind the vibration frequency of the tuning fork.

Group B.

7. What do you mean by the specific heat of a substance ?

Sp. ht. of a Substance 15-1-6.

A lump of platinum weighing one hundred grammes is heated in a flame until its temperature has reached that of the flame. It is then removed and dropped quickly into a calorimeter which has a water-equivalent of 5 grammes and contains 495 grammes of water. If the temperature of the water rises from 22°C., to 30°C., find the temperature of the flame. (The specific heat of platinum is ·0365.)

Vapour Tension.

8. What do you mean by the expression *vapour tension* ?

Three barometer tubes are filled with mercury and their open ends plunged into a vessel of mercury in the usual way. Into the vacum of one a little air is introduced, and into that of the other a few drops of water. What will be the effect in each case on the height of the mercury of plunging the three tubes further into the cistern ? Give reasons for your answer.

9. What is the cause of the cooling effect produced

in a room, when a grass (*khus khus*) screen moistened with water is placed in front of the door.

Steam at 100°C. is allowed to pass into a vessel containing 10 grammes of ice and 100 grammes of water at 0°C. until all the ice is melted and the temp. is raised to 5°C.. Neglecting the water equivalent of the vessel and the loss due to radiation, etc., calculate how much steam is condensed. (The latent heat of steam=536, and the latent heat of water=80.) **Lt heat of Steam.**

SECOND PAPER.

Only SEVEN *questions are to be answered which must include either question 1 or question 2 of Group A and question 1 of Group B.*

Group A.

1. Describe with full experimental details a method of determining the focal length of a convex lens. **Focal length of a convex lens**

Solve the following problem by drawing a diagram to scale, with the help of the squared paper provided. An object, 6 centimetres high, is placed at a distance of 40 centimetres from a thin convex lens and an image is formed on the other side of the lens, the height of the image being 4 centimetres. Find the focal length of the lens approximately.

2 Explain the formation of images by a concave mirror **Images by Concave mirror. 13. II. 3.**

An object, height 5 centimetres, is placed at a distance of 40 centimetres from the surface of a concave mirror (measured along the axis of the mirror) whose radius of curvature is 20 centimetres. Find the position and the size of the image, *without calculation*, as in the preceding problem.

3. Why do opaque objects appear coloured? Why does a mixture of ordinary blue and yellow pigments appear green? How would you make a stick of red sealing wax *appear* black? **Colour '09. II. 2.**

4. You are given a slit, a convex lens, a screen, and a prism: show how you would arrange these to obtain a pure spectrum. Explain how it is that the spectrum is not pure when the lens is not used. **Pure spectrum. '10 II. 3. '13. II. 2 '14. II. 4**

GROUP B.

Electro-static Induction.

1. A metal globe (insulated) is charged with positive electricty. (*a*) Another insulated metal globe without any charge is placed near it. (*b*) The latter globe is momentarily connected with the earth. (*c*) both are then enclosed in an insulated case. (*d*) The case is connected to earth. Explain what will happen in each case and how you will proceed to test your conclusions.

Constant Cell. 14. II. 7

2. Describe any *two* arrangements for maintaining a steady current of electricity in a given wire. Explain the mode of supply of energy for maintaining it in the two cases. What becomes of the energy as it continues to flow?

3. State Ohm's Law.

Ohm's Law. 10. II. 5

A battery of ten cells, joined in series, yields a current of 1 ampere when the external resistance is 10 ohms, and a current of ·6 ampere when the external resistance is 20 ohms. Find the E.M.F. and the internal resistance of one of the cells (these being the same for all.)

Electro-Mag. Induction. 09. II. 5 13. II. 10 14. II. 9.

4. You are provided with a suitable voltaic cell; a suitable galvanometer; a soft iron rod; and two pieces of wire one of considerable length and the other short. Explain, with the help of a diagram, how you would arrange to demonstrate the production of induced currents.

Action of current on Galv. needle.

5. A small magnet movable about a vertical axis, is placed at the centre of a circular coil lying in the plane of the magnetic meridian. (*a*) At first, no current passes. (*b*) A current is passed. (*c*) The number of turns in the coil is increased, the current being unchanged in strength. (*d*) The coil is slowly rotated about the vertical diameter. Explain what happens in all these cases.

How to magnetise; 13. II. 9 Lines of force of a magnet. 14. II. 8.

6. Describe the various ways of magnetizing a piece of soft iron. How would you trace the lines of force in the neighbourhood of a bar-magnet? Indicate how the shape of the lines you get depends on the earth's magnetism.

ANSWERS.

FIRST PAPER—1911.

1. When energy is lost or expended in doing work. an equal amount of energy is gained or produced as the equivalent of the work done. Thus a body, or system of bodies, may lose energy in one form, and gain an equal amount of energy in some other form; or a body, or system of bodies, may lose energy by doing work on some other body or system of bodies, which thus gains an equal amount of energy as the equivalent of the work done on it.

When a quantity of energy is lost or expended in this way in one form, and is gained or produced in some other form, it is said to be *transformed*, or to undergo *transformation*, but whatever the nature of the transformation may be, the quantity of energy produced is always equal to the quantity expended or lost.

Thus, when a body falls freely through any distance it loses an amount of gravitational potential energy equal to the work done by the weight of the body during the fall, and gains an amount of kinetic energy also equal to the work done by the weight; that is, the body loses a quantity of gravitational potential energy, and gains an exactly equal quantity of kinetic energy.

Similarly, in the case of the bob of a simple pendulum in vibration the bob loses gravitational potential energy, and gains kinetic energy in falling, and it loses. kinetic energy and gains gravitational potential energy in rising. In moving over any portion of its path, however, the energy lost in one form is exactly equal to the energy gained in the other form, each being equal to the work done by or against the weight of the bob. The vibration energy of the bob thus remains constant, but is subject to periodic transformation from potential energy to kinetic energy, and from kinetic energy to potential energy.

In the same way when a body in falling raises another body, the potential energy lost by the falling body is equal to the potential energy gained by the body raised, together with the kinetic energy gained by the two bodies. The total energy of the two bodies considered as one system thus remains constant.

This is the principle known as the principle of *Conservation of Energy.* Maxwell states this principle in the following form :—

The total energy of any material system can neither be increased nor diminished by any action between the parts of the system, though it may be transformed into any of the forms of which energy is susceptible.

(*a*) When the train is moving on a level country with uniform speed the energy derived from the burning of the coal in the engine is spent up in overcoming the forces of friction which opposes the motion of the train. This energy is equal to the work done by the engine.

(*b*) In this case over and above that mentioned in case (*a*) a portion of the energy supplied by the burning coal is expended in taking the train up-hill against the attraction due to gravity.

2. See *Text book.*

Pressure per unit area on the plate

=atmos. press.+press. due to 100 cms. height of water.

=press. due to $76\times13{\cdot}6$ cms. ht. of water+that due to 100 cms. ht. of water.

=press. due to $(76\times13{\cdot}6+100)$ or $1133{\cdot}6$ cms. ht. of water.

=weight of $1133{\cdot}6$ c.c. of water=$1133{\cdot}6$ gms.

And, area of the plate=$10\times100\times10\times100$ sq. cms.=10^6 sq cms.

∴ the total pressure on the plate $=10^6\times1133{\cdot}6$ gms.

$=1133{\cdot}6\times981\times10^6$ dynes.

3. To determine the density of the body very roughly and without using a balance, we may just float the cube of wood in water and measure the part of it that floats out of water.

Let l =length of the cube

and l^1=length of the side of the cube out-side water.

The vol. of displaced water=$l^2(l-l^1)$ c.c.

∴ wt. ,, ,, ,, $=l^2(l-l^1)$ gms., which must be the weight of the cube

∴ density of cube$=\dfrac{\text{its mass}}{\text{its volume}}=\dfrac{l^2(l-l^1)}{l^3}=\dfrac{l-l^1}{l}.$

In the example given,—

wt. of water displaced$=200+50=250$ gms.

,, ,, liquid ,, $=200+W$ gms, say

$$\text{But sp. gr. of liquid} = \frac{\text{wt. of liquid}}{\text{wt of equal vol. of water}}$$

$$\text{Or} \qquad 1{\cdot}2 \quad \frac{200+W}{250}$$

Whence $W=100$ gms.

Therefore, further wt. to be added on the pan$=50$ gms.

4 For the statement and verification of Boyle's Law see *Glazebrook-Heat. Art. 75* or *De.-Prac. Physics. pp. 112-115.*

The example given may be taken in two senses. The first one is that the volume of air in the faulty barometer is wanted when the true barometer reads 760 mm. In the second one the vol. of the air at a press. of 760 mm. simply is wanted.

In the first case,

Vol. of air enclosed in the faulty barometer$=10$ c. c.

Its pressure$=(75-74)$ or 1 cm. height of mercury.

When the true barometer reads 76 cms. the mercury level in the faulty one will rise, say, through x cms. Let α be the cross-section of the faulty barometer tube.

Then altered vol. of air$=(10-x\alpha)$ c. c.

And the new pressure $=\{76-(74+x)\}=(2-x)$ cm. height of mercury.

Applying Boyles' Law, we get.

$$PV=P'V'$$

$$\text{or} \qquad 10\times 1=(2-x)(10-x\alpha).$$

In this case, no definite solution can be arrived at without the value of α.

In the second case,

$P=$ press. due to 1 cm. height of mercury

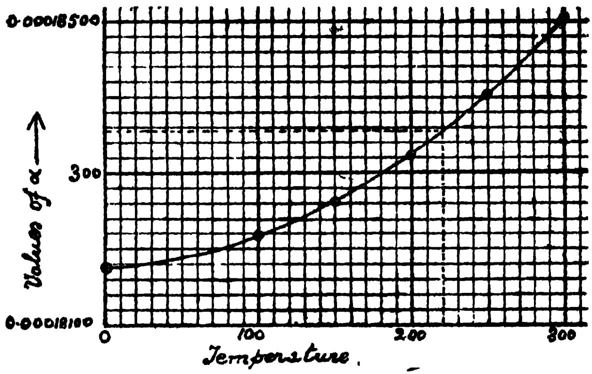
$V=10$ c.c.

$P_1=76$ cms. of mercury.

$$\therefore \qquad V_1=\frac{PV}{P_1}=\frac{10\times 1}{76}=\cdot 132 \text{ c.c. approx.}$$

5. In the Graph drawn on the other page,

X axis represents temperature in C.
1 small div. along it=10°C
and Y-axis represents co-efft. of expansion of mercury
1 small div. along it=0·00000020.



The value of α at 200°C from the graph is ·0018355.

6. A body emitting a musical note is in a state of regular vibration, the vibrations being rapidly executed. For a note to be audible its no. of vibrations per sec. must be between the limits of audibility. For the nature of vibration of sonorous bodies, see *De' Sound*, *Art* 5, *Page* 7.

In the medium round the vibrating source of sound the vibrations of the body give rise to longitudinal waves consisting of alternate layers of condensations and rarefactions which travel out in all directions See *De Sound, Page* 12 *Art* 7.

To find the frequency of the given fork proceed as in *art.* 35 *De.* – *Sound* and then see *art* 75.

7. For specific heat see *Glazebrook, Heat, Art* 34.

Heat lost by Platinum $=$ mass $\times$ sp. ht. $\times$ fall of temp.
$= 100 \times 0{\cdot}0365 \times (t - 30^\circ)$
t being the temp of the flame.
$= 3{\cdot}65 \times (t - 30)$ calories.

Heat gained by cal. etc $= (495+5)\ (30^\circ - 22^\circ)$
$= 4000$ calories

And Heat lost by Platinum = Heat gained by calorimer
i.e. $3{\cdot}65\ (t - 30^\circ) = 4000$
Whence $t = 1126$°C app.

8. Vapours like gases, exert pressure on all sides of the vessels in which they are contained. This pressure is called the vapour tension. This is different for different vapours. For the same vapour the tension varies with temperature in general. For the same temperature the tension of a vapour increases with the quantity of vapour formed but can not be greater than a value which is constant for the temperature. This is then known as the saturation pressure of the vapour for that temperature.

The behaviour of the three tubes will be as follows :—

In the beginning, the height of mercury column in each tube is, of course, such as to indicate the atmospheric pressure. Say, it is 76 cm., the space above it being a vacuum.

When the first tube which is allowed to remain a true barometer, is pushed down into the cistern, mercury column would be unaffected until the top of the tube comes to touch it. Then as the tube is further lowered, the mercury column would be obliged to come down, exerting all along an upward pressure against the closed top of the tube, which gradually increases and is always equal to the height of the column in a true barometer minus the reduced height of the mercury column in the tube.

In the second tube which contains air above the mercury level, the height to begin with is less than that in a true barometer. As the tube is lowered the volume of the air diminishes accordnig to Boyle's Law (*i. e.* PV=constant, temperature remaining the same), the pressure exerted on the air being always equal to the atmos. pressure minus the pressure of the reduced mercury column.

As the third tube, in which a few drops of water have been introduced and immediately converted into vapour, is lowered the vapour will behave like the air in the second case so long as it is unsaturated. When with the gradual diminution of volume the space containing the vapour becomes saturated, the vapour tension will attain its maximum value at the temperature at the time of the experiment which is constant and may be obtained from the difference of atmospheric pressure and the press. of the reduced mercury column in the tube. As the tube is still further lowered, water-vapour is condensed, the mercury column remaining at the same height until all the vapour is converted into water. After this stage the mercury and water will descend together with the tube, the pressure against the top of the tube increasing as in the first case.

9. In evaporation unit mass of water absorbs a quantity of heat (which is called the latent heat of vaporisation) from the surrounding air which thus becomes cooled. So to keep a room-

cool a *khus khus* screen moistened with water is hung up in front of the door or window.

In the example given.—

Heat given out by

(1) m gms. of steam at 100°C in condensing to water at 100°C $= m \times 536$.

(2) m gms of water at 100°C in cooling to 5°C $= m.(100-5) = m. \times 95$.

Heat gained by

(1) 10 gms. of ice at 0° to melt into 10 gms. of water at 0°C $= 10 \times 80 \cdot 1$ units

(2) 110 gms. of water at 0° to be raised to 5°C $= 110 \times 5$.

Now heat given out = heat absorbed

$\therefore (536+95)\ m = 801+550.$

or $631\ m = 1351$

whence $m = 2 \cdot 14$ gms.

SECOND PAPER.—1911.

1. For the experimental determination of the focal length of a convex lens see *De'-Prac. Physics p. 185* (Explain the UV method.)

Draw a figure after *fig. 94 Glasebrook.—Light*, where let AQ represent 40 cm. Draw PQ=6 cm. Cut off AM from AC such that AM=4 cm. Through M draw MP, a line parallel to the principal axis of the lens.

Now draw the central ray PA which we know would pass through the thin lens without being deviated in its course. Let this ray meet MP at p. Draw pq perp. to the axis. Evidently pq is the image under the given conditions.

Next take a ray from P parallel to the principal axis. It meets the lens at R. On passing through the lens the ray is deviated to the principal focus F, of the lens and will then meet the central ray at p which is the image of the point P. So join RP.

Then the intersection of Rp and Aq is F.

Measure AF on the same scale on which AQ = 40 cms.
and show that AF = 16 cms.

2. For the formation of images by a concave mirror see *Text book*.

Tabulate your results thus :

Position of object.	Image.			Figure.
	Position.	Nature.	Size.	
At ∞	At F	Real, inverted	Point	*Glazebrook, fig.* 64
Bet ∞ and C	Bet. F and C	,,	Smaller	,, 66
At C	At C	,,	Equal	,, 67
Bet. C and F	Bet. C and ∞	,,	Larger	
At F	At ∞	,,	Very Large	
Bet. F and mirror	On the negative side of mirror	virtual, erect	Larger	,, 68

For the solution in the example given, draw a fig. after that given in *Glazebrook, fig.* 66, *page* 91. Let AQ represent 40 cms. and AO 20 cms. on the same scale ; also let PQ represent 5 cms. not necessarily on the same scale. Complete the construction for the image in the usual way, then measure Aq on the scale along the principal axis. This gives the position of the image. Measure $p\,q$ on the same scale as along PQ · this gives the size.

3. See the answer to *Q* 2–*I*–1909.

To make the stick of red sealing-wax appear black, it is to be placed under any colour of the spectrum except the red ; for, all but the red colour will be absorbed by the sealing-wax.

4. For the arrangement to get a pure spectrum see *De. Prac. Physics. p.* 192. For the discussion on the purity of spectrum see *Glazebrook-Light. Art.* 111.

GROUP B.

1. (*a*) Electrostatic induction takes place. The positive charge on the first globe will induce and attract negative charge to the side of the second globe nearest to it, and induce and repel an equal quantity of positive to the side furthest away from it.

In order to test the above, let a proof plane touch the charged globe and be then separated ; let a pith ball, suspended by silk

thread, share the charge of the proof plane, the pith ball will be repelled when taken near the furthest end of the second globe, thus proving that the charge on this is positive. On the other hand it will be attracted by the other end of the second globe, where the induced charge is a negative one.

(*b*) On the second globe being momentarily connected with the earth, the induced positive charge escapes to the earth.

(*c*) According to the principle of induction, each of the induced charges is equal to the inducing charge, provided the charged body is well within the other, so that all the lines of force starting from the former end at the latter. In this case, the induced negative charge remaining on the second globe is slightly smaller than the inducing positive charge. Thus a few lines of force, may end at the insulated metal case, thus making it slightly negatively charged, if at all, to be tested by putting it in connection with a galvanoscope.

(*d*) On the case being connected to the earth the leaves of the gold-leaf electroscope will collapse if they had diverged at all in (c).

2. Fully describe a Daniell and a Bunsen cell giving the description of parts and chemical action going on in each cell.

The energy is dissipated by the heating of the wire.

3. For Ohm's Law. See *page 75 of this book.*

In the example given—

If E. be the E. M. F. of each cell and r its internal resistance.

$$\text{We have} \quad C \quad \frac{10\,E}{10r+10}$$

$$\text{also} \quad 0{\cdot}6 \quad \frac{10\,E}{10r+20}$$

Whence $r=0{\cdot}5$ and $E= 1{\cdot}5$ volts.

4. It is to be assumed that the two pieces of wire given are insulated. Wind the shorter piece of wire, round the soft iron rod and connect its ends to the terminals of the cell. Convert the longer wire into a coil such that the soft iron rod with the coil round may go inside, and connect its terminals to the galvanometer. Now proceed as in *Poyser, page 285*. Sum up your answer by giving the table in *Page 286.*

5. (*a*) The magnet will point north and south, lying in magnetic meridian.

(*b*) When a current is passed through the coil, a magnetic field will be created due to which the ends of the needle will be urged at right angles to the magnetic meridian. The needle will come to rest making a deflection θ with its former direction, when the moment of the couple due to earth's force on it is equal and balanced by the moment of the couple due to the current. Here we have the case of a Tangent galvanometer, such that $C = k \tan \theta$.

(*c*) When the number of turns is increased,, the current remaining the same, the force due to the current increases and hence the deflecion too.

(*d*) As the coil is turned towards the needle, the latter is further deflected until it is overtaken by the coil; in the latter case, it is called a sine galvanometer and $C = k \sin \theta_1$.

6. For the methods of magnetisation which are

(1) Single Touch
(2) Separate Touch
(3) Double Touch
(4) Electric method

See *text-book*.

For the method of tracing lines of force, see *De' Prac Physics pp.* 208-11.

The existence of regions, called the neutral regions (see fig. 100, *ibid.*) can be ascribed to the influence of the earth's magnetism on the field due to the magnet.

1912

FIRST PAPER

Paper-Setters. { DR. D. N. MULLICK. / MR. C. W. PEAKE. / MR. R. S. TRIVEDI. }

Only **seven** *questions are to be attempted. All questions are of equal value.*

Graph.

1. Draw a curve, on the squared paper supplied, to indicate the height above ground, at intervals of half a second, of a body falling freely from rest at a height of 150 ft. Find from your graph the position of the particle after 1·67 seconds.

Laws of Pendulum
13-I-2
15-I-2

2. State the laws of oscillation of a simple pendulum. Find the length of a simple seconds pendulum at a place where g is 981.

When a ball suspended by a string is made into a 'seconds pendulum,' does the actual length of its string equal the length of the equivalent simple pendulum? If not, why?

Archimedes Principle
'14-I-3

3. State Archimedes' Principle, and explain how it may be used to distinguish a metal from its alloy.

1 litre of hydrogen and a litre of air weigh about 0·09 gramme and 1·3 grammes respectively at a certain temperature (t) and pressure (p). What will be the capacity of a balloon weighing 10 kilogrammes, which just floats when filled with hydrogen having the same pressure (p) and the same temperature (t) as the air?

Transformation of energy
'11-I 1
'13-I 1

4. It is said that most forms of terrestrial energy are derived ultimately from the sun. Explain the meaning of the statement, and discuss its truth with special reference to the energy of combustion of charcoal and of coal gas, and the kinetic energy of a running stream.

Gas Laws. Co-effi of exp. at constant volume.

5. State concisely the relations between the volume, pressure and temperature of a gas. Describe an experiment to prove the relation between pressure and temperature when the volume is constant.

What volume does a gramme of carbonic acid gas occupy at a temperature 77°C and half the standard pressure? (1. c.c. of carbonic acid gas weighs ·0019 gramme at 0°C and standard pressure.)

6. What is meant by the statement that the latent heat of fusion of ice is 80? Lt. Ht. of fusion

A litre of hot water is poured into a hole in a block of ice at 0°C., which is immediately closed by a lid of ice. After a time the hole is found to contain a litre and a half of ice cold water. What was the original temperature of the water? '12-I-5 '13-I-5

7. Discuss as fully as you can the grounds on which we conclude that 'radiant heat' is but 'invisible light.' Radiant heat.

8. State the law connecting the velocity of sound through a gas with its density. Compare the velocities of sound in hydrogen and oxygen under similar conditions. Compare further the lengths of two organ pipes filled with these two gases when they give the same musical note. (Density of oxygen is sixteen times that of hydrogen.) Vel. of Sound in a gas

9. Distinguish clearly between the loudness and the pitch of a musical note. On what physical conditions of the sounding body do they respectively depend? Loudness 'C-9-17 Pitch '14-I-8

A vibrating tuning fork is held near the mouth of a tube closed at one end. The tube is found to 'speak.' Explain why this happens. Assuming the velocity of sound in air to be 320 metres per second and the length of the tube to be 32 cm., what will be the time of oscillation of the fork? Pitch by Resonance 09-I-6 '11-I-6 '14-I-9

SECOND PAPER.

Only SEVEN *questions are to be attempted. All questions are of equal value.*

1. State the laws of refraction of light. Explain how they are experimentally verified. Deduce from these laws the condition of total internal reflection of light. Describe some phenomena depending on total reflection. Laws of Refraction '14 II-1 Total Int. reflection.

Spectrum of Sunlight.
'15-II-13
Min div. of a prism.

2. A broad beam of sunlight passes through one face of a glass prism, the prism being held perpendicularly to the beam, and is thrown on a white screen. Describe, as accurately as you can, the appearance of the patch of light on the screen and also its movements as the prism is rotated round its axis. Trace the path of any one of the rays incident on the prism.

Images by convex lens.

3. A convex lens of focal length 10 cm. is made to approach a rod of length 5 cm. placed perpendicularly to the axis of the lens. Show by means of typical diagrams, drawn to scale (on the squared paper provided), the changes in the nature and the size of the image.

Telescope
14 II 3
Microscope
'15-II-4

4. Give a brief description of (*a*) the astronomical telescope, and (*b*) a compound microscope, showing by a sketch how the image is formed in each case.

On Electrostatic Induction.

5. Two plates (*A*, *B*) of brass are supported on glass handles and placed facing each other: (*a*) one of the plates (*A*) being connected to a frictional machine and the other (*B*) to a gold-leaf electroscope, the machine is worked for some time. (*b*) The plate *A* is disconnected from the machine and (i) it is moved nearer the other, (ii) a plate of glass is interposed between them. (*c*) The plate *A* being disconnected from the machine, the plate B is momentarily connected to the earth and then (i) the plate *A* is moved nearer to *B*, (ii) a plate of glass is interposed between them. Explain what happens in each case.

On C- E'R.
Effect of a Current.
'13-II-7
'14 II-9
'15-II-7

6. Find the electromotive force which will maintain a current of 1·5 amperes through a resistance of 10 ohms.

Mention any three phenomena which are associated with the passage of an electric current, and describe suitable experiments by which they can be shown.

Magnetic and Electro static induction.

7. A bar magnet is divided in the middle and the parts are separated. An insulated conductor (cylindrical, with the ends rounded off) is placed in front of an electrified ball, with its axis passing through the centre of the ball; and while in presence of the ball the cylinder is divided in the middle and the further half is removed to a great distance. Contrast and explain the state of affairs in the two cases.

8. Describe a simple method of comparing resistances. Comparison of resistances

An electric current of 5 amperes is divided into three branches, the lengths of the wires in the three branches being proportional to 1, 2, 3; find the current in each. [The wires are of the same material and cross section.]

9. How would you make an electro-magnet? What kind of material is most suitable for its core? Why? Electro magnet. '15-II-8

An electro-magnet of cylindrical form is placed with its axis (AB) horizontal and perpendicular to the magnetic meridian. C is the centre of a small magnet, so that C is in AB produced. State what should be the direction of the current in order that the north pole of the needle should be deflected towards the electro-magnet.

10. A toothed wheel is capable of rotation about a horizontal axis perpendicular to its plane. Describe in detail an electro-magnetic arrangement for producing continuous rotation of the wheel. Specify the direction of rotation corresponding to the particular arrangement you propose. Barlow's wheel.

ANSWERS.

FIRST PAPER,—1912.

1. The space traversed by a body in time t falling from rest can be obtained from the formula :—

$$s=\tfrac{1}{2}gt^2$$

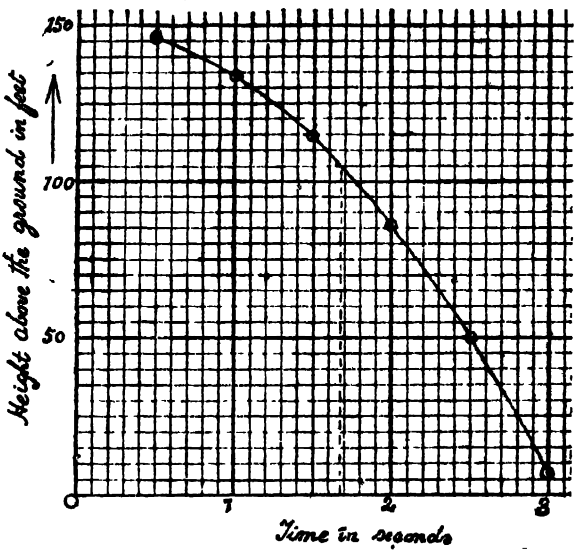
Taking $g=32$ *ft. per sec. per sec.*, and calculating the distances fallen through at the end of every half second, the following table has been prepared.

TIME IN SECONDS.	1/2	1	1 1/2	2	2 1/2	3
HEIGHT FALLEN THROUGH.	4	16	36	64	100	144
HEIGHT ABOVE GROUND IN FEET.	146	134	114	96	50	6

In the graph

" 1 small div. along X axis = 0·1 sec.

" " Y " = 5 ft.



In 1·67 seconds, the required height above the ground, from the graph, is 105 ft.

2. For the four laws of oscillation, see *Text books*. For the example see *Ex. 1. page 1 of this book*. The ideal simple pendulum is one in which a mass concentrated at one point is suspended by a weightless string, the length of the pendulum being measured from the point of suspension down to this point. In a practical case, as the bob has a certain size, the length of the equivalent simple pendulum is obtained not from the actual length of the string but by measuring the length from the point of suspension to the centre of gravity of the ball, where the whole mass of the ball, may with sufficient accuracy, be supposed to be concentrated.

3. For the statement of Archimedes' principle see *Text-book*.

A metal can be distinguished from its alloy by applying Archimedes' principle in the following way:—

Let the wt. of the substance $= w$ gms.

Immerse the body in water. Let its wt. in water $= w_1$ gms.

Loss of wt. of the body in water $=(w-w_1)$ gms.

$\therefore$ Vol. of displaced water $=(w-w_1)$ c.c.

and this must also be the vol. of the body.

$\therefore$ density of the body=

If the density thus found does not happen to be the the same as in the case of a pure metal, it is then an alloy.

In the example. the balloon of 10 kg. wt. is supported by the buoyancy of the hydrogen which is $=1{\cdot}3-0.09=1{\cdot}21$ gms. per litre.

$\therefore$ $1{\cdot}21\times$capacity per litre$=10$ kg. $=10\times1000$ gms.

$\therefore$ Capacity in litres $=8264{\cdot}46$.

4. Directly or indirectly the sun is the source of nearly all the available energy we possess. For our food we are indebted to the sun, Vegetable life depends on sunshine. Our fuel—coal is due to the sun's action which in past time enabled plants to decompose the carbonic acid of the air and store up the carbon which we use. The winds and tides, the rainfall which feeds our rivers and is the source of our water power, all depend on solar action. Life, as we know it, would be impossible without the sun.

The energy of charcoal which becomes potent on combustion, is again attributed to the sun. Charcoal is, as we see, derived by the incomplete combustion of wood, the water from the latter being driven out. Vegetables, again live and grow under the sun; they absorb juices or watery food from the earth and get nourishment from the atmosphere helped by sun's radiation. It is in the presence of the sun's rays that chlorophyll or the green colouring matter in the leaves of plants can decompose carbon-dioxide present in the air and absorb carbon. Thus solar energy coming from different sources is stored up as potential energy in a piece of wood which when burnt, liberates this energy in the form of energy of heat accompanied by light energy.

Again, the coal gas is a product of incomplete combustion of coal which is raised from mines where wood was converted into coal being subjected to great pressure for thousands of years. So the energy of the gas, which can be utilised by burning it, is derived from the stored-up energy of the coal, which, as we have already seen, is derived from the sun.

Vast quantities of sea-water are being daily evaporated under the action of the sun's rays : the vapours so formed, condensing into clouds in the higher regions of atmosphere. This water comes down to the earth in the form of rain, which feeds the running streams, to flow down to the sea, its place of birth. The energy of the running stream is thus derived from the potential energy of the clouds, of which again the source is the solar energy.

5. The relation between P and V when T is constant is given by Boyle's Law (See *Text-book.*)

The relation between V, and T, when P is constant, is given by Charles' Law (see *Text-book*). The two laws are combined in the formula.

$$\frac{PV}{T} = \frac{P'V'}{T'} = \text{a constant, say R.}$$

$$\therefore \quad PV = RT$$ [See *Glazebrook, Heat, page 108.*

From the above formula the relation bettwen pressure and temperature of a gas when volume remains unaltered, can be deduced ; we have then

$$\frac{P}{T} = \frac{P'}{T'}$$

i.e., P varies directly as the absolute temperature. See *Glazebrook. Heat, page 104* for the experiment, to be performed with a Constant Volume Air Thermometer.

In the example given,

1 c.c. of gas at 0°C and 760 mm. weighs 0.0019 grm.

$\therefore$ 1 gm. of gas occupies $\frac{1}{0{\cdot}0019}$ c.c. or 526·3 c.c. at 0°C and 760 mm.

Again we have $\frac{PV}{T} = \frac{P'V'}{T'}$.

Here P=760 mm. V=526·3 c.c. and T=273° absolute and P'=380 mm. T'=273+77=350° absolute.

Substituting, $\frac{760 \times 526{\cdot}3}{273} = \frac{380 \times V'}{350}$

Whence V' =1349·5 c.c.

6. The statement means that the quantity of heat required

to melt, 1 gm of ice at 0°C to 1 gm of water at the same temperature is 80 heat-units *i.e.* is such as can raise the temperature of 1 gm. of water through 80°C or that of 80 gms. of water though 0°C. This is called latent because its presence within the body is not registered by the rise of mercury level in a thermometer.

In the example given,

Heat given out by 1 litre or 1000 gms. of water at T°C in falling to 0°C.

$$=1000 \times (T-0) \text{ calories.}$$

This heat is utilised in converting a quantity of ice into half a litre or 500 gms. of water *i.e.* the mass of ice melted is 500 gms.

$\therefore$ Heat taken up by 500 gms. of ice in being converted to water at $0^\circ = 500 \times 80 = 40{,}000$ calories.

$\therefore$ $1000 \times T = 40{,}000$ whence $T = 40°C$

7. Herschel found that as he moved a sensitive thermometer through the solar spectrum from violet to red, it showed only a little rise of temperature in the blue end, a little more in the green, a large rise in the red end and even for some distance below the red end *i.e.* even in the invisible part of the spectrum, the thermometer was sensibly heated. Since then, it has been known that as glass absorbs a greater part of the *dark heat rays*, a prism of rock-salt should be used instead, and the thermometer replaced by a lampblacked thermopile. (After this see *Glazebrook, Art. 160, Experiment 50 (a)*

In fact, both heat and light waves are due to vibrations in the ether differing only in frequency or the number of vibrations per second. (See the excellent remark on this point in *Glazebrook, Light, Art. 135, para third*).

8. For the first part of the question see *De-Sound, Art. 18. P. 31.*

For the latter part of the question suppose l and l^1 are the lengths of the two organ pipes (say closed) filled with hydrogen and oxygen respectively. Then from the formula in the case of such a pipe, we have when the pipes are in unison

$$n=\frac{V}{4l}=\frac{V^1}{4l^1}$$

where V ond V^1 are the velocities of sound in the two gases respectively.

$$\frac{l}{l^1}=\frac{V}{V^1}=\frac{\sqrt{d^1}}{\sqrt{d}}=\frac{\sqrt{16}}{1}=4.$$

$\therefore$ the hydrogen pipe must be 4 times as long as the other pipe.

For loudness and pitch of a note see *De' Sound, Art. 47.*

The latter part of the question is an instance of Resonance. For explanation see *Art 74. De.—Sound.*

In the example given, we have

$$V = n\lambda \qquad \text{but } l = \lambda/4 \text{ or } \lambda = 4l$$

$$\therefore \quad V = 4nl$$

$$n = \frac{V}{4l}$$

$$= \frac{320 \times 100}{4 \times 32} = 250.$$

$\therefore$ Time for one complete oscillation $= \frac{1}{250}$ sec. $= 0{\cdot}004$ sec.

SECOND PAPER.—1912.

1. For the laws of refraction see *Glazebrook–Light. Art 33.*

For experimental verification see *Ganot, Art 531.*

Condition of total reflection :—If a ray of light passes from a denser medium into a rarer medum, it is bent away from the normal, *i.e.* the angle of refraction ϕ' is greater than the angle of incidence ϕ, such that the refractive index of the denser medium compared to the first is given by

$$\mu = \frac{\text{Sin } \phi'}{\text{Sin } \phi}$$

As ϕ increases ϕ' also increases. Let ϕ attain a value θ when the corresponding value of ϕ' is 90° *i.e*, when the refracted ray just grazes along the surface of separation of the two media. Then

$$\mu = \frac{\text{Sin } 90}{\text{Sin } \theta} = \frac{1}{\text{Sin } \theta}$$

For any value of ϕ greater than θ, no refraction is possible. The ray suffers total internal reflection retaining the greater part of its intensity, This value of θ is called the critical angle for the media concerned.

The mirage is a phenomenon due to total reflection from layers of air. For figure and explanation see *Ganot, Art. 356.*

For other instances see *Glasebrook Arts* 38 (*c*), 40 (*a*) *and* (*b*).

2. An impure spectrum is formed on the screen. For its description see *Glazebrook. Light. Art 107. Expt. 19* (*a*),

As the prism is rotated, the spectrum shifts. There is a certain position of the prism when the deviation of the bright patch is the minimum. See *Art 107. Expt. 29* (*b*) *ibid.*

To trace the path of a ray see *fig. 122 ibid.*

3. Here $f=10$ cm. Put the object at varying distances from the lens. Draw a diagram in each case and tabulate your observations mentioning in each case the value of u taken by you and the corresponding value of v, and the size of the image you actually get.

Object Dis. In words.	Object Dis. In cms.	Pos. of Image. In words.	Pos. of Image. In cms.	Nature of Image.	Size of image.	Figure.
Beyond $2f$ and at a great dis.	...	bet f and $-2f$	...	Real inverted	Diminished. I =cms.	*See Galzebrook Light. fig. 94*
„ but nearer	...	„	...	„	Increases in size	„
At $2f$	...	at $-2f$	...	„	Equal in size, I= cms.	—
Creater than f but less „ $2f$	...	beyond $-2f$	...	„	Larger I= cms.	*ibid. fig. 93*
At F	10	at ∞	...	„	Very large.	—
Bet. F and Lens.	...	beyond F	...	virtual erect.	Larger I= cms	*ibid. fig. 92*

4. For description of astronomical telescope—See *Glazebrook Light, Art, 98.*

For that of compound microscope See *Art. 101 ibid.* You are to draw a diagram in each case.

5. First draw a diagram.

(*a*) A becomes charged say, with + ve elect. This will induce and attract — charge on the side of B nearest to it, while the induced free charge will be repelled on the furthest end of B and will diverge the leaves of the electroscope.

(*b*) (i) As A is made to approach B, there will be greater induction between A and B, as some more of the lines of force from A would now turn towards B; and there will be greater divergence of the leaves connected with B.

(ii) As glass is interposed between the two plates, the intensity of the field decreases due to a less number of lines of force passing through from A to B and the divergence of the leaves diminishes.

(*c*) The leaves collapse, the free charge on B passing to the earth.

6. We have from Ohm's Law

$$E = CR = 1 \cdot 5 \times 10 = 15 \text{ volts.}$$

For the second part of the question.—

The three important phenomena associated with the passag of an electric current are due to its

(1) Heating effect—see *Poyser Experiments 141-43*
(2) Electrolytic effect—see „ „ *176*
(3) Magnetic effect —see „ „ *144*

7. A bar-magnet has a N-seeking pole at one end and S-seeking one at the other. When it is divided in the middle, the broken ends show polarities such that each broken piece is again a complete magnet with two poles. Thus an isolated magnetic pole can never be obtained in practice. (*See Poyser, Experiment 12 page 7*).

The charge on the ball induces and attracts a charge of the opposite kind to the end of the cylinder nearest to it, while induced charge of the same kind is repelled to the other end of the cylinder. When the two parts of the cylinder are separated, each part contains either all the induced positive or all the induced negative charge; further, as all points on the surface are at the same potential, there would be no flow of charge at the time of separation.

8. See *De' Practical Physics page 270*, Wheatstone bridge method of comparing resistances. Or if a voltmeter to measure E.M.F. is available, put all the resistances in series with a battery; the same current will, of course, pass through every part of the

circuit. As Ohm's Law, $C=E/R$ is not only true for the whole circuit but for a part of the circuit as well, we have

$$C=\frac{E_1}{R_1}=\frac{E_2}{R_2}=\frac{E_3}{R_3}$$

where E_1, E_2, E_3 etc are the diff. of potentials between the terminals of the given wires respectively, measured by the voltmeter and R_1, R_2, R_3 etc. are their resistances.

Hence $R_1 : R_2 : R_3$ etc $= E_1 : E_2 : E_3$ etc.

The second part of the question is an example of divided circuit.

Let E be the P. D. bet. the two points when the resistances R_1, R_2, R_3 are joined in multiple arc. Let C_1, C_2, C_3 be the currents in the three branches and C the total current$=5$ amperes.

We have $E=C_1R_1=C_2R_2=C_3R_3$.

Whence $C_2=C_1\frac{R_1}{R_2}=C_1\times\frac{1}{2}$; and $C_3=C_1\frac{R_1}{R_2}=C_1\times\frac{1}{3}$.

$\therefore \quad C=C_1+C_2+C_3=C_1\times\frac{11}{6}=5$ amperes.

Hence $C_1=\frac{30}{11}$ amp. $\quad C_2=\frac{15}{11}$ amp. $\quad$ and $C_3=\frac{10}{11}$ amp.

9. Coil an insulated copper wire so as to make a helix round a bar of soft iron. When a current is allowed to flow through the coil, the bar becomes strongly magnetised, the combination being called an electro-magnet.

Soft iron is the most suitable material to serve as a *core* for an electro-magnet, as it possesses a great susceptibility and a small retentivity; in other words, as soon as the current is turned up it immediately turns into a powerful magnet and becomes demagnetised just as the current is stopped. This is a necessity for the working of many instruments, such as Electric bells, Telegraph transmitters, Ruhmkorff's coil etc.

In the second part of the question, the end of the electro magnet nearest to the needle must attract the north of the compass needle. This happens when the current will seem to flow clock-wise in the coil when looked at from the side of the needle.

10. The case is one of Barlow's Wheel. For description and diagram, see *Poyser, page 242, fig. 215 and Ganot, page 663.*

The direction of rotation depends upon that of the lines of force in the field and the direction of the current.

1913.

FIRST PAPER.

Paper-setters. { DR. J. C. BOSE. / MR. D. N. Mullick. / MR. R. S. TRIVEDI. }

Only SEVEN *qnstions are to be attempted. All questions are of equal value.*

Conservation of Energy '11-I-1 12-I-4

1. State the principle of the conservtaion of energy. Illustrate the principle by taking some simple examples.

Laws of Pend. 12-I-2 15-I-2

2. State the laws of oscillation of a simple pendulum. Deduce the effect of temperature on the period of oscillation of a compound pendulum.

3. How would you determine the specific gravity of a solid ?

Sp. Gr. of a Solid 09 I-8 15-I-3

A cubical block of wood of specific gravity of 0·7 floats in water, just completely immersed, when a body of unknown weight is placed on it. Find the weight of this body, if the volume of the block of wood is 100 c. c.

4. State Boyle's law. Describe a method of verifying it experimentally.

Boyle's Law 11-I-4 15-I-1

What volume does a gramme of hydrogen occupy at 0°C, when the height of the mercurial barometer is 750 millimetres ? [1 c.c. of hydrogen weighs 0·0008958 grammes at 0°C. and 760 millimetres.]

Lt. heat 09-II-3 12-I-5

5. Explain the meaning of latent heat. How would you determine the latent heat of fusion of ice ?

Explain the cooling effect of a fan.

To find α 14-I-7

6. Describe an experiment to determine the co-efficient of linear expansion of a metal rod.

A copper rod is found to be 5·0009, 5·0018, 5·0027 metres long at temperatures 10°C., 20°C. and 30°C. respectively. Find, by means of a graph, its length at 0°C. Determine also the coefficient of expansion.

7. Explain how a knowledge of the boiling point of water would enable us to determine the barometer pressure. **Barom Press. from boiling point.**

Into the Torricellian vacuum of a barometer water is introduced drop by drop till some water is left over. From the depression of the mercury column it is possible to determine the temperature of the room. How ?

8. Describe a method of determining the vibration frequency of a tuning-fork. **Pitch of a fork** **'15-I-8**

If the frequency of a tuning-fork is 400 and the velocity of sound in air is 320 metres per second, find how far sound travels while the fork executes 30 vibrations.

9. A sonometer string is stretched with a force of 200 grammes weight. (*a*) The force is increased to 800 grammes. (*b*) The length of the string is halved. How is the pitch of the note emitted by the string affected in each case ? **Vibration of a String.**

SECOND PAPER.

Only SEVEN *questions are to be attempted. All are of equal value.*

1. State the laws of reflection of light. How would you verify them experimentally ? **Laws of Reflection** **'15-II-1**

PQ is an incident ray at a plane surface. If Q' is any point on the reflecting plane, show that $PQ+QR$ is less than $PQ'+Q'R$.

2. Describe an arrangement of apparatus by which a solar spectrum may be projected on the screen. Describe such a spectrum, and give a general explanation of the dark lines in the spectrum. **Pure spectrum** **'10-II-3** **'11-IIA-4** **14-II-4**

3. A concave mirror of focal length 8 cm. is made to approach a rod of length 4 cm. placed perpendicularly to the axis of the mirror. Show, by means of typical diagrams on the squared paper provided, the changes in the nature and size of the image. **Images by Concave mirror** **11-IIA-2**

Magnifying glass

4. Explain how a single convex lens may be used as a magnifier. Trace the path of the rays by which an object would be seen in such a case.

Gold leaf Electroscope

5. Explain the use of a gold-leaf electroscope. How would you charge it by induction ?

An electrified ball is made to approach an uncharged gold-leaf electroscope till it touches the electroscope. Describe and explain the effects observed.

Electrophorous
'14 II-5
Condensing Electroscope
'15 II-6
Leyden jar
'14-II-3

6. Explain the action of (*a*) an electrophorus, (*b*) a condensing electroscope, and (*c*) a Leyden jar. In charging a Leyden jar the outer coating is (*a*) insulated (*b*) connected to earth. What difference does it make ?

Electro-Static and electro-dynamic discharge
'12 II-6
'14-II-9
'15-II-7

7. Mention any three phenomena associated with the passage of (*a*) 'frictional', (*b*) 'voltaic' electricity. Describe suitable experiments by which they can be demonstrated.

Tangent Galv.

8. Describe and explain the action of a simple form of tangent galvanometer.

With a single Leclanche's cell and a given circuit of a total resistance (including that of the cell and galvanometer) of 10 ohms, I get a certain deflection in the galvanometer. When the cell is changed, as well as well as the resistance of the circuit, so that the deflection is again the same, it is found that the total resistance of the circuit (in the second experiment) is 15 ohms. Compare the electromotive forces of the two cells.

Magnetic Induction
'14-II-10
Magnetisation
11-II-6

9. What is magnetic induction ? How would you distinguish between a permanent magnet and a magnetic substance ?

Describe as many methods as you can of magnetising a piece of soft iron.

E. M. Induction
'09 II-5
11-IIB-4
14-II-9

10. Give a brief account of the principal phenomena of electro-magnetic induction, illutsrated by typical experiments.

ANSWERS.

FIRST PAPER—1913.

1. See *the answer to Q 1—I—1911.*

2. For the four laws of oscillation, see *Text-book.*

The period of oscillation of a pendulum at a temp. t is given by

$$T = 2\pi\sqrt{\frac{l}{g}} = 2\pi\sqrt{\frac{l_0(1 \times \alpha t)}{g}}$$

where l_0 is the length of the pendulum at 0°C and α is the linear co-eff. of expansion of the pendulum rod.

$$\text{At } 0^\circ\text{C}, \; T_0 = 2\pi\sqrt{\frac{l_0}{g}}$$

$$\therefore \quad T = T_0\sqrt{(1+\alpha t)}.$$

Hence the period increases for a rise of temperature. Thus, when temperature increases, a clock loses and *vice versa.*

3. See *Text Book.*

Let the wt of the body $= w$ gms.

and the wt of the block $= 100 \times 0{\cdot}7 = 70$ gms.

According to the condition of floatation,

weight of block + that of the body on it

= upward press. due to water displaced by the block

= wt. of 100 c c. of water

or $70 - w = 100$ gms. whence $w = 30$ gms.

4. $0{\cdot}0008958$ gm. of Hydrogen at N. T. P. occupies 1 c.c.

$\therefore$ 1 gm of Hydrogen will occupy $\frac{1}{0{\cdot}0008958}$ c.c. at N.T P.

Now $PV = P^1V^1$

Substituting $760 \times \frac{1}{0{\cdot}0008958} = 750 \times V^1$

Whence $V^1 = 1131$ c.c. nearly

5. For the meaning of Latent heat see *De' Practical Physics p. 139.*

For the determination of Latent Heat, see *page 160 ibid.*

A fan is able to produce a cooling effect in two ways (1) by accelerating evaporation from a wet surface (2) by promoting ventilation by the speedy removal of hot air and thus producing a breeze of fresh cold air.

6. For an experiment to determine α of a metal rod, see *Glazebrook, Art 56.*

Let the X axis on a square paper represent temp starting from the zero degree, and the Y-axis, the length in metres.

Plot the given points and connect them. The graph will be a straight line. Produce the straight line to meet the Y-axis. Then the ordinate enclosed between this point and the X axis gives the length at 0°C. It will be seen from the graph that this is 5 metres.

Hence α is given by

$$\alpha = \frac{\text{Change in length}}{\text{length at } 0^\circ C \times \text{rise of temp.}}$$

$$= \frac{5\cdot009-5}{5 \times 10} = 0\cdot00018$$

7. We know that water, in fact any liquid, boils at a temperature at which the pressure of its vapour is equal to the superincumbent pressure. So noting the temperature of boiling water at any place we are to consult Regnault's Table of pressure of aqueous vapour. The pressure at the observed temperature is the required atmospheric pressure.

As water is introduced drop by drop into the Torricellian vacuum, more and more water vapour will be formed and the mercury level will go down more and more when the space will be saturated with the vapour and the process of vaporisation will stop. The pressure of the aqueous vapour has now been the maximum pressure at the temp. of the room, which is constant and is measured by the depression of the mercury column. Hence, consulting again the above mentioned table we get the room temperature.

8. For the method to determine the frequencies of fork see *De' Sound-Chap. X.* Any method may be given,—preferably that of resonant column of air. See *Arts 56* and 75.

For the example given,

In the time of 400 vibration of the fork *i.e.* in one sec., sound travels 320 metres.

Hence in the time of 30 vibrations of the fork viz. in 30/400 sec., sound will travel $\frac{30}{400} \times 320 = 24$ metres.

9. Let n be the frequency of the note emitted by the string when the stretching force T = wt. of 200 gms.

Now in the case of transverse vibration of a string the expression for n is

$$n = \frac{1}{2l}\sqrt{\frac{T}{m}} \quad \text{where}$$

l = length of string.
T = tension of string in dynes.
m = mass in gms. per unit length. of string.

(*a*) In the formula given above let T = 800 gms. and n = pitch of the corresponding note emitted. Then,

$$\frac{n_1}{n} = \sqrt{\frac{T_1}{T}} = \sqrt{\frac{800}{200}} = 2.$$

(*b*) Let n_2 be the pitch of the note when the length is halved Then,

$$\frac{n_2}{n} = \frac{1/\frac{1}{2}l}{1/l} = 2.$$

So frequency is again doubled *i. e.* the first higher octave is heard.

SECOND PAPER,—1913.

1. For the laws of reflection of light see *Glazebrook, Light Arts*, 23 and 24 or *Ganot Art*, 332.

The latter part of the question is on the principle of Least Path in the case of reflection. Draw a figure.

Draw PNP′ normal to the mirror, and produce RQ to meet PP′ at P′. Join PQ′.

Then, since PN = P′N, we have by geometry, PQ = P′Q and PQ′ = P′Q′.

$$\text{But} \quad P'Q' + Q'R > P'R$$
$$i.\,e. \quad > PQ + QR$$

2. For the production of a solar spectrum, see *Glazebrook, Light Art, 107 Expt.* 29 (*b*).

The sun is assumed to consist of an incandescent solid or liquid nucleus, surrounded by a comparatively cooler envelope in which oxygen, hydrogen, iron, calcium etc., are present in the form of gases or vapours. Now, the vapour of an element absorbs the waves which it would itself emit if it were incandescent. The white light, emitted by the solar nucleus which consists of luminous vibrations of all frequencies, is robbed, in passing through the solar atmosphere, of those waves which vibrate in the same periods as the elements there present. (See *Glazebrook, Light Art 121*).

3. Proceed just in the same way as shown in *Q. 2–II—1911* only take $f=8$ cms. and $O=4$ cms. here.

Sum up your observations in a tabular form (also shown), in which the values of v and I in cms. corresponding to the values of u taken in cms., should be pu .

4 A convex lens is used as a magnifier when the object looked at, is within the focal length of the lens. A virtual, erect and magnified image appears to be formed on the same side as the object. For the fig. see *fig 92 Glazebrook, Light.*

5. See *De. Prac. Physics, page* 229.

There will be induction on the electroscope due to the presence of the charged body, the leaves diverging with the induced charge of the same kind while the induced charge of the opposite kind is attracted to the top.

As the charged ball approaches the electroscope, induction is stronger and consequently the divergence of the leaves increases.

When the ball is made to touch the electroscope the inducing charge is neutralised by the induced charge of the opposite kind at the top of the electroscope, while the induced charge of the same kind on the leaves spreads over the conducting part of the electroscope and the surfaces of the balls which are now in contact with each other. In fact, the case has now become a case of conduction, and the divergence of the leaves is consequently noticed to diminish.

6. (*a*) See *Poyser, page 89*

(*b*) " " " *134*

(*c*) " " " *122*

(*a*) When the Leyden jar is charged with the outer coating insulated, the potential of the latter is very nearly equal but slight-

ly smaller than that of the inner coating; so from the formula $Q = CV$ where V is the diff. of pot. between the two plates, Q, the charge imparted to the Leyden jar will be small, for the capacity C is constant, depending on the size of the coating and the distances between them.

(*b*) When the outer coating is earth-connected its potential falls to zero, hence the diff. of pot. between the two coatings increases, therefore the quantity of charge the Leyden jar can receive is much greater.

7. Frictional electricity does easily give rise to big sparks by means of which a flame can be lighted or gun-powder burnt. The mechanical effect of the discharge from a Leyden jar can be demonstrated by letting the discharge pass through a thin glass plate when the latter is pierced through. Again, the physiological effect is well demonstrated by the shock experienced when the discharge from a Leyden jar takes place through the body. (See *Poyser, page 132. Expts. 98 and 99.*)

(*b*) For the phenomena associated with the passage of voltaic electricity, see the answer to *Q 6—II—1912.*

8. For the description of Tangent Galvanometer see *De' Pract. Physics, page 249* and for the action and formula, see *Poyser, pages 245-47.*

In the example given,

In the first case—

$$C = \frac{E_1}{10} \quad \text{where } E_1 \text{ is the } e.m.f. \text{ of the 1st cell.}$$

In the second case—

$$C = \frac{E_2}{15} \quad \text{where } E_2 \quad ,, \qquad ,, \qquad \text{2nd cell.}$$

since the deflection is the same in both cases.

Therefore $E_1 : E_2 = 10 : 15 = 2 : 3.$

9. For magnetic induction, see *Poyser, page 11.*

A magnetic substance is one which can be acted upon by a magnet and is attracted by either pole of a magnet. But a permanent magnet has got fixed polarities and can be attracted by one pole and repelled by the other pole of a known magnet when the latter is presented to the same end of the former.

For the methods of magnetisation see *Poyser, page 15.*

10. See *Poyser page 285-86.* Sum up your conclusion by adding the table given there.

1914.

FIRST PAPER.

Paper-setters. { DR. D. N. MULLICK. / MR. C. W. PEAKE. / MR. R. S. TRIVEDI. }

Only SEVEN *questions are to be attempted. All questions are of equal value,*

Spring balance

1. Describe a spring balance.

A set of observations taken with a spring balance is given thus :

Weights in the pans (in grammes.)	10	20	30	40	50	60	70	90
Extension (in millimetres.)	0	13	20	24·5	30·5	38·5	42·[illegible]	55

By means of a graph, find the (approximate) relation between these quantities. Find the magnitnde of the weight that will extend the above spring by 40 mm.

Press. in a liquid

11-I-2.

2. How would you prove experimentally that a liquid exerts pressure in all directions.

A tall vessel provided with a tap at the side, near the bottom is filled with water and made to float upright on a thick plate of cork. Explain what will happen when the top is opend.

Archimedes' Principle

12-I-3.

3. State Archimedes' principle. How would you verify it experimentally.

A piece of metal of specific gravity 8·9 weighs 15.8 grammes in water. Find its value.

Evaporation ;

4. Explain the meaning of evaporation and ebullition. Describe suitable experiments to illustrate their meaning.

Boiling under dim press.

A flask is half filled with water and heated till the water boils. After a short time, when the upper part of the flask is filled with steam, it is well corked and inverted. Cold water is now poured over the flask. What will happen ? Why ?

Ht. from Boiling Pt.

5. Explain how you are able to determine (approximately) the height of a mountain, by finding the boiling points of water at its top and bottom.

6. Explain how the specific heat of a solid may be determined by means of the ice-calorimeter. **Sp. ht. by Ice calorimeter**

A mass of 500 grammes of copper is heated in an oil bath and then placed in an ice-calorimeter. If 150 grammes of ice are found to be melted, find the temperature of the oil bath. [Specific heat of copper =0·0933.]

7. Define the coefficients of linear and cubical expansion. **Lin Co-eff. of exp.**

A bar 50 cm. long is heated from 14°C. to 98°C. If the increase in length is 0·7 mm., find the coefficient of linear expansion. 15-I-4.

8. What do you understand by the pitch of a musical note? **Pitch** 12-I 9.

Two organ pipes of the same length are given, one open, the other closed. What should be the relation between the pitch of the fundamental notes emitted by them? **Organ pipes**

9. You are provided with a vessel containing water, a glass tube about 40 cm. long, open at both ends, and, a tuning-fork whose frequency is 256. Explain how, with these, you would determine the velocity of sound. What experimental result do you expect? [The velocity of sound in air is 33280 cm. per second nearly.] **Vel. of Sound by Resonance** '09-I-6 '11 I-6 '12-I-9

SECOND PAPER.

Only SEVEN *questions are to be attempted, all of which are of equal value.*

1. State the laws of refraction of light. Explain how they may be experimentally verified. **Laws of Refraction**

A coin placed in a basin is hidden from view by the side of the vessel. When water is poured into the vessel, the coin just comes into view. Explain the phenomenon by means of a diagram. 12-II-1.

2. Show how to find by a geometrical construction the position of an image formed by a (thin) double convex lens. **Images by Convex lens** '15-II-2

Find the size of the image on the squared paper provided, the size of the object (placed symmetrically with its centre on the axis) being 5 cm, and its distance 30 cm. from the lens. [The focal length of the lens = 10 om.]

Telescope '12-II 4.

3. Trace the path of the rays in a simple telescope focussed for a very distant object, the object glass and the eye-peice each consisting of a single thin double convex lens.

Pure Spectrum '11-II A-4 '10-II-3 '13-II-2.

4. Light from an illuminated slit is brought to a focus on a screen, after being passed through a double convex lens. A prism is then placed between the lens and the screen. What will be the effect? Trace the path of the rays.

Charging a Leyden Jar. 13-II-6 **Eletrostatic machine** 13-II-6

5. How would you charge (*a*) an insulated metallic conductor, (*b*) a Leyden jar by induction? Describe a simple form of electrical machine for producing 'static' electricity.

Ice-pail Expt 15-II-5

6. On an insulating stand is placed a metal can, the outside of which is connected to a gold-leaf electroscope.

A charged metal ball hanging by a silk thread is gradually let down into the vessel, till it rests on the bottom. Describe and explain the effects produced.

Constant cell 11-IIB-2

7. Describe a constant cell (any form).

A current of 0 2 ampere passes through a circuit of resistance 10 ohms. Find the E. M. F. of the cell producing the current. [The internal resistance of the cell is negligible]

Lines of force of a magnet 11-IIB-6

8. Explain how you would trace the lines of force in the neighbourhood of a magnet.

Detection of a current 12-II-6 13-II-7 15-II-7

9. What is an electric circuit? Describe two methods by which you could detect the existence, and determine the direction of an electric current flowing in the circuit.

Telephone

10. Explain the action of a telephone.

ANSWERS.

FIRST PAPER,—1914.

1. For the description of a spring balance see *Text-book*

Take a piece of square paper, let the X axis represent the weight in gms. and let the Y-axis, the extensions in mm. Plot the points for the given readings and draw the mean line through them. The graph will be a straight line.

It will be seen that to produce an extension of 40 mm. a weight of about 64 gms. will be necessary.

2. See *Text-book.*

The vessel moves away in a direction opposite to that of the issuing jet.—an illustration of the lateral pressure in a liquid (See *Ganot, page 99, Art, 88.*)

3. For Archimedes' principle and its experimental verification, see *Ganot Art, 105*)

Let V be the vol. of the body in c.c.
Then its wt. $=$ vol. $\times$ density $= 8{\cdot}9 \times V$.

And wt. in water $= 8{\cdot}9\ V -$ wt. of displaced water
$= (8{\cdot}9\ V - V)$ gms. $= 15{\cdot}8$ gms.

Therefore $V = 15{\cdot}8 / 7{\cdot}9 = 2$ c.c.

4. For evaporation, See *page 123 Glazebrook, Heat*
,, ,, ,, Arts, 120 and 122 ,, ,,

For the latter part of the question see *Art,* 121 ,

5. We know that water (in fact any liquid) boils when the pressure of its vapour is equal to the super-incumbent pressure. We are to note the two temperatures at which water boils on the summit of a mountain and its base. By consulting Regnault's tables of pressure of aqueous vapour at different temperatures we can find the pressure of the atmosphere at the two places and hence their difference. Very complete tables have again been constructed by which the difference in height between any two places may be readily ascertained, if the corresponding difference of pressure be known. For small elevations we may assume that an ascent of 900 ft. produces a depression of 1 in in the barometric height.

The above comes to an approximation that an ascent of about 1080 ft. produces a lowering of $1°C$ or that of 600 ft. produces a lowering of $1°F$ in the boiling point of water.

6. For the determination of sp. ht. of a solid, Black's method may be adopted, see *Glazebrook, Heat. Art 48, page 44.*

Let T be the temp. of the oil bath

Heat lost by Copper = Heat gained by ice

or, Mass of Copper × its sp. ht. × fall of temp. = Mass of ice melted × Lt. ht.

i. e. $508 \times 0{\cdot}0933 \times (T - 0) = 150 \times 80.$

whence $T = 257^\circ C$ approx.

7. For definition of α, see *Glazebrook, heat Art 55.*
" " " β " " " 63.

In the example given, we have the formula

$$l' = l\{1 + \alpha(t' - t)\}$$ see *page* 21 *of this book,*

$\therefore$ expansion $\doteq l' - l = l\alpha(t' - t)$

Here $t' - 0\ 7$ m.m. $= 50 \times \alpha \times (98 - 14)$

$= \alpha \times 50 \times 84 = 4200 \times \alpha.$

whence $\alpha = 0{\cdot}00016.$

8. For the pitch of a note, see *De.—Sound Art* 57,

In the latter part of the question, the pitch of the fundamental of the open pipe is an octave higher than that of the closed pipe of the same length. (see *Art. 69, ibid.*)

9. Hold the glass tube vertically in the jar dipping one end in the water. Hold the vibrating fork close to the upper end and adjust the height of the tube over water until it speaks. When the resonance is maximum, the wave-length in air of the note is given by four times the length of the tube over water. (See *De, Sound, Expt. 18 page 53 and Art. 74.*

From the condition of resonance in the case of vibration of air in a closed pipe, we have $v = 4\,l\,n.$

where v = vel. of sound in air,
l = length of the vibrating air-column
and n = the frequency of the note.

Here $33280 = 4 \times l \times 256$

Whence $l = 32{\cdot}4$ cms. approx.

Thus, we expect that in the experimant, maximum resonance will occur when the length of the tube above the water-surface will be about 32·4 cms.

SECOND PAPER. 1914.

1. For the statement of the laws, see *Glazebrook. Art 33.*

For the experimental verification. see *Ganot. Art 351.*

For the second part of the question, see *Glazebrook Light, Expt. 9 page 50.*

2. For the geometrical construction for the formation of an image by a double convex lens, *Glazebrook Light, Art 74* and *77.*

Draw a figure on the square paper provided, after *fig. 94 Glazebrook Light,* where AQ is to represent 30 cms. and AF' 10 cms. on the seme scale. As the object is placed symmetrically on the axis, PQ is to represent 2·5 cms. not necessarily on the same scale. The semi-length of the image is given by *pq* on the same scale as PQ. The size of the image will be 2·5 cms.

3. Describe an astronomical telescope, see *Glazebrook-Light, page 160. Art 98.*

4. A pure spectrum would be obtained. For figure and discussion, see *Glazebrook-Light, Art 111.*

5. (*a*) The insulated metallic conductor can be charged either by conduction or by induction. In conduction, this is simply to be put in contact with a charged body or an electrical machine.

In induction, a charged body is to be brought near the conductor. The induced opposite charge is attracted or *bound* by the inducing charge to that part of the conductor nearest to it, while the induced similar charge is repelled to the furthest end and passes to the earth when the conductor is momentarily connected with the latter. Now remove the conductor away from the charged body when the opposite charge will no more be bound and will spread over the whole surface of the conductor.

To charge a Leyden jar by induction :—Draw first a sectional figure of a Leyden jar.

Place the jar on an insulating table, take the charged body (say with + ve electricity) near the knob of the jar, it will induce —ve charge on the knob and + ve charge on inner foil. The latter again induces —ve charge on the inner side of the outer coating and + ve charge on the outer side.

On touching momentarily the outer coating with the hand the free + ve charge on it will pass to the earth. On now removing the charging body the two opposite charges on the inner coating cannot neutralise as the case has now become similar to a standard

case of induction where the—ve charge on the inner face of the outer coating may be regarded as holding the +ve charge on the outer face of the inner coating bound to it. Now, on touching the knob the free —ve charge will pass to earth leaving the Leyden jar on the insulator charged as in the ordinary way.

For the second part of the question, you may describe, either an eletrophorous (see *Poyser, page 89*) or an electric machine (Ramsden or Voss machine, see *Poyser, Ch. X.*

6 The experiment is commonly known as Faraday's ice pail experiment;—for full description see *De' Prac. Physics, pp.* 226-28.

7. Describe either a Daniell or a Bunsen cell; see *Text-book.*

In the example given :—

we have E=CR=0·2 x 10=2 volts.

8. The field about a magnet can be mapped accurately by a small compass needle and roughly by iron filings (See *De, Practical Physics, page* 208 *etc*)

9. The entire path through which a current flows is called an electric circuit.

The detection of a current and the determination of its direction can be effected by two means ;—

(*a*) by the magnetic effect of a current, *i.e.* by the deflection of a magnetic needle from the magnetic meridian (the experiment being known as the O'ersted experiment see *De, Prac. Physics, page* 240). The direction of the current is given by Ampere's rule-*page* 241 *ibid.*

(*b*) by the electrolytic effect of the current When an electrolyte is decomposed by means of a current, the Hydrogen and metallic ions are liberated at the cathode, the electrode connected with the negative plate of the battery.

Let the current pass through between two copper plates dipped in copper sulphate solution, the plate on which a fresh deposit of copper occurs, shows that it is a cathode plate. (See *Poyser, page* 268)

10. For the figure and action of a Telephone, See *Poyser page 313*.

1915.

FIRST PAPER.

Paper-setters { DR. D. N. MULLICK.
MR C W. PEAKE.
MR. R. S. TRIVEDI.

Only SEVEN *questions are to be attempted. All questions are of equal value.*

1. State Boyle's law. Describe an experiment you would perform for verifying the law. **Boyle's law** 11-I-4.

A litre of air weighs 1·293 grammes at a pressure of 76 cm. and temp. 0°C. What will be the weight of a litre of air at the same temperature, when the barometer stands at 78 cm.? 13 I-4.

2. State the laws of the pendulum. **Laws of pendulum** 12-I 2. 13 I-2.

The following readings were obtained with a simple pendulum -

Length	Time of oscillation	Length	Time of oscillation.
20 cms.	·45 sec	80 cms.	·94 sec.
30	·55	95	·98
42	·65	102	1·01
55	·74	115	1·07
70	·835	130	1·14.

Represent by a graph the relation between length and time, and find from your graph the time of oscillation of a simple pendulum of length 50 cm.

3. Why does a solid appear to weigh less in water than in air? Describe a method of determining the specific gravity of a solid. **Sp. Gr of a Solid** 09 I-8.

A piece of metal weighs 100 grammes in air and 88 grammes in water. What would it weigh in a liquid of specific gravity 1.5. 13 I-3.

4. Define co-efficient of linear expansion. **Linear Exp.**

The length of a copper rod at 50°C. is 2·00166 metres, and at 200°C. it is 2.00664 metres. Find its length at 0°C. and the coefficient of expansion of copper. 14 I 6

Cub. exp. of a gas

5. Why it is necessary to take account of the pressure of a gas in determining its coefficient of cubical expansion ?

200 c. c. of air at 15°C. is raised to 65°C. Find the new volume. the pressure remaining unchanged.

Sp. ht. of a body

11-I 7

6. How would you determine the specific gravity of a liquid ?

If 90 grammes of mercury at 100°C. be mixed with 100 grmmes of water at 20°C., and if the resulting temperature be 22°C., what is the specific heat of mercury ?

Vap. press of a liquid

7. Describe an experiment to show that the vapour pressure of a liquid exposed to air at its boiling point is equal to the atmospheric pressure.

Forced vibration

Pitch of a fork

13-I-8

8. Explain why, when the handle of a vibrating tuning fork is pressed against a thin wooden board, the intensity of sound is greatly increased.

Explain a method of determining the vibration frequency of a tuning fork.

On $v=n\lambda$

9. The velocity of sound in hydrogen is 1296·5 metres per second. What will be the length of a closed organ pipe filled with hydrogen which gives a note having a vibration frequency of 512 per second ?

SECOND PAPER.

Only SEVEN *questions are to be attempted. All questions are of equal value.*

Laws of Reflection

13-II-1

1. State the laws of reflection of light. Show by means of a diagram that a man can see the whole of his person in a mirror, the length of which is half his own height.

Images by Convex lens

14-II-2

2. Show how to find by a geometrical construction the position of an image formed by a thin convex lens.

An object, 2 in long, is placed (symmetrically with its centre on the axis) 8 inches from such a lens. Find by means of a diagram, the position and the length of the image, given that the focal length of the lens is 4 inches. [Squared paper is provided.]

Spectrum

12-I.-3

3. Light from a slit is allowed to fall on a prism. State and explain with the help of a diagram what will be observed when the slit is illuminated (1) by a sodium flame, (2) with white light.

4. Describe a compound microscope and trace the path of the rays. Microscope 12-II-4

5. Explain the meaning of the expression electrification by induction. How would you prove that positive and negative electricities are produced in equal quantities by friction ? Ice-pail Expt 14-II-6

6. Explain the principle and the action of a condensing electroscope. Condensing Electroscope 13-II-9

7. Describe any two effects of an electric current, whereby the direction of the current may also be determined. Effects of a Current 12-II-9 13-II-7 14-II-9

8. What is an electro-magnet ? Explain (1) the action of an electric bell *or* (2) the principle of the electric telegraph. Electro-mag. 12-II-9 Electric bell, Telegraph

9. Describe typical experiments to illustrate the phenomena of electromagnetic induction. E. M Ind. 09-II-5 11-II B-4 13-II-10

10. Describe suitable experiments illustrating the phenomena of magnetic induction. How would you determine whether a given steel rod is a magnet or not ? Mag. Ind. 13-II-9

ANSWERS.

FIRST PAPER, 1915.

1. For the statement of Boyle's Law and an experiment to verify it, see *De' Prac. Physics page*, 112 *etc*.

In the example given :—

The vol. that a litre of air at 76 cms. will occupy at 78 cms. is given by

$$V^1 = \frac{PV}{P^1} = \frac{76 \times 1000}{78} \text{ c.c.}$$

Hence the wt. of V^1 c.c. of air at 78 cms.

$$= 1 \cdot 293 \text{ gms.}$$

$\therefore$ wt. of 1 litre of air at the same temp. and press.

$$= \frac{1 \cdot 293}{V^1} \times 1000 = \frac{1 \cdot 293 \times 78 \times 1000}{76 \times 1000}$$

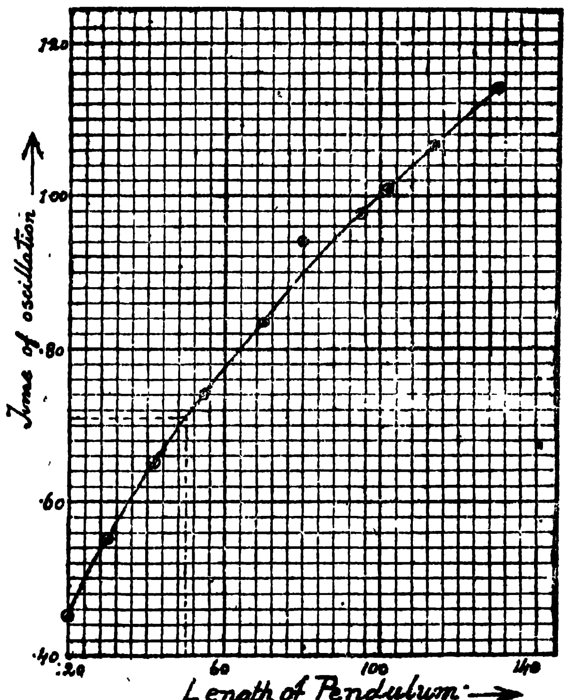
$= 1 \cdot 327$ gms. approx.

2 For the laws of pendulum see *Text-book.*

In the graph given below

X axis represents length in cms. 1 small div. = 4 cms.

Y axis represents time of oscillation 1 small div. = 0·2 sec.



From the graph the reqd. time of oscillation is found to be 0·71 sec.

3. When a solid is immersed in a liquid, say, water, it displaces a quantity of the liquid equal to its own volume and is consequently acted upon by an upward pressure. According to Archimedes'

principle, this upward pressure is equal to the weight of the displaced liquid. Hence a solid appears to lose a part of its weight when immersed in a liquid.

For the method of determination of the specific gravity of a solid, see *De' Pract. Physics page 100 etc.*

In the example given :—

Loss of wt. of metal in water $=100-88=12$ gms.

$\therefore$ Vol of displaced water $=12$ c.c.
$=$ vol. of the body.

$\therefore$ vol. of the liquid displaced $=12$ c.c.

Hence the wt. of liquid displaced $=12\times 1{\cdot}5=18$ gms.

$\therefore$ wt. of the body in the liquid $=100-18=82$ gms.

4. For definition of α, see *Glazebrook, Heat Art 55.*

In the example given .—

We have $l^1=l\{1+\alpha(t^1-t)\}$ (see *pags 21 of this book*)

$\therefore\ l^1-l\ =l\alpha(t^1-t)$

Here $2{\cdot}00664-2{\cdot}00166=2{\cdot}00166\times\alpha\times(200-50)$.

or $0{\cdot}00498=300{\cdot}249\,\alpha$

whence $\alpha={\cdot}0000167$

Again $2{\cdot}00166=l_0(1+50\times{\cdot}0000167)$

whence $l_0=\dfrac{2{\cdot}00166}{1{\cdot}000835}$

$\therefore$ $\log l_0=\log 2{\cdot}00166-\log 1{\cdot}000835.$
$={\cdot}3013882-{\cdot}0003625.$
$={\cdot}3010257$
$=\log 1{\cdot}99998.$

$l_0=1{\cdot}99998$ metres.

5. Co-efficient of cubical expansion, γ of a gas. involves the determination of change of volume of the gas due to a rise of temperature. It is obvious that the change of volume considered here should only be effected by alteration of temperature. Altera- of volume due to change of pressure is obviously not to be counted here. Hence an experiment to determine γ must be conducted with a constant pressure.

In the example given :—

We have $\frac{V}{T}=\frac{V^1}{T^1}$ see *page* 28 *of this book.*

Here $\frac{200}{273+15}=\frac{V^1}{273+65}$

whence $V^1=\frac{200\times 338}{288}$

$\therefore$ $\log V^1=\log 200+\log 338-\log 288.$
$=2\cdot3010300+2\cdot5289167-2\cdot4593925.$
$=2\cdot3705542 \quad =\log 234\cdot722$

$\therefore$ $V^1=234\cdot722$ c.c.

6. In this question *specific gravity* is obviously meant for *specific heat.*

The specific heat of a liquid can be determined by the method of mixture, viz., by raising some solid of known mass and specific heat to a given temperature, immersing it in a known mass of the liquid contained in a calorimeter of known weight and then measuring the rise of temperature. The equation for distribution of heat is as follows—

Heat lost by solid
$=$ mass of solid $\times$ its sp. ht. $\times$ fall in temp.
$=$ M. S $(T-\theta)$

Heat gained by liquid
$=$ its mass $\times$ sp. ht. $\times$ rise of temp
$=$ $m.\ s.\ (\theta-t).$

Heat gained by calorimeter, etc
$=$ $m'\ s'\ (\theta-t).$

$\therefore$ MS $(T-\theta)=m\ s\ (\theta-t)+m's'\ (\theta-t).$

Whence s can be found

In the example given, let S be the sp. ht. of mercury.

Heat lost by mercury
$=90\times S\,(100-22)=7020$ S calories

Heat gained by water
$=100\times(22-20)\ =200$ calories.

$\therefore$ 7020 S $=$ 200, whence S $=\cdot0285.$

7. See *Glazebrook, Heat, page* 138 *Expt.* 36 (*a*) *or* (*b*).

8. The first part of the question is an instance of forced vibration, see De' sound, *Art* 33 (*vi*).

For determining the frequency of a fork, any of the following methods may be resorted to.

(1) The vibroscope method.
(2) Syren
(3) Resonance column (see *De sound Ch. X*).

9. For the expression for the pitch of a note emitted by a closed organ pipe, we have (see *page 63 of this book*) $v = 4nl$

Substituting in the above equation, we get

$$1296\cdot5 = 4 \times 512 \times l$$

whence $l = 1\cdot579$ metres, approx.

SECOND PAPER 1915.

1. For the laws of reflection see *Glazebrook, Light Art* 23.

Draw a diagram from the following—Draw a line AB to represent the man's height. Let the mirror M be at a distance d in front of it; then draw the image, on the other side behind the mirror, equal to the object and at a distance d from the mirror. Join the top of the object with the top and foot of the image by two lines; then, it follows from simple geometry that the portion of the mirror intercepted between these lines=half the image=half the man's height.

2. For the geometrical construction for an image formed by a thin convex lens see *Glazebrook,—Light Art.* 74 *and* 77.

Draw a figure on the squared paper provided after *fig.* 93 or 94 in *Glazebrook Light.* where AQ is to represent 8 in., and AF' (AF) 4 in. in the same scale. PQ, the semi-length of the object is 1 in. Twice the length of pq is the size of the image.

Note that as the object is placed at $2f$ from the lens, the image will be formed at $2f$ on the other side of the lens, the image being real, inverted and equal in size to the object.

3. (1) With sodium light only a yellow band will be obtained on the screen formed at the same place where the yellow of the solar spectrum appears.

(2) With white light a spectrum will be obtained. Draw a figure. See *Glazebrook Light Art.* 107 *Expt.* (*a*) *and* (*b*)

4. For description of a compound miscroscope see *Glazebrook Light p.* 165.

5. When an electrically charged body is taken near to an insulated uncharged conductor, the lines of force proceeding from the former terminate at the side of the conductor nearest to the charged body, thus making that surface charged with the opposite kind of electricity. The inducing charge and the induced charge are thus held 'bound;' to each other. At the same time and equal quantity of charge of the same sign is also induced on the conductor and is repelled to its furthest end It is 'free' to move away if a second conductor be connected with the first one. This is what is meant by electrification by induction.

For the simultaneous and equal development of both kinds of electricity see *Poyser. p.* 82. *Expt.* 60.

6. For the description of a condensing electroscope see *Poyser p.* 134.

7. The direction of a current can be determined by

(*a*) the effect of the current on a magnetic needle placed near it, and

(*b*) by the electrolytic effect of the current.

(see the *answer to* Q. 9—II—14).

8. For an electro magnet see *the answer to* Q. 9-II 12.
For the description of an electric bell, see *Poyser page, 31*..

Every electric telegraph consists essentially of three parts : —

(1) a *circuit*, consisting of a metallic connection between two stations and a source of electric current ;

(2) a *communicator* or sender for the signals from one of the stations ; and

(3) an *indicator* or *receiver*, for receiving them at the other station.

The manner in which these arrangements especially the last two,are effected can be greatly varied.

(See *Poyser, page 308* and *p. 301 etc.*)

9. For typical experiments to illustrate the phenomena of electromagnetic induction see *Poyser, page 285*.

10. For magnetic induction see: *Poyser, pages 11-12.*

If the steel rod be a magnet it will possess opposite polarities at the two ends. Hence the same pole of a known magnet will attract one end and repel the other end of the given steel rod, if magnetised. Otherwise there would be attraction due to induction in both the cases. Hence it is said that repulsion is a surer test on the point than attraction.

1916.

Paper-setters { Dr. D. N. Mullik. Mr. C. W. Peake. Mr R. S. Trivedi.

FIRST PAPER.

Only SEVEN, *questions are to be attempted. The questions are of equal value.*

1. Define 'work' and 'energy.' Give simple examples of transformation of energy. **Conservation of energy. 11-1A-1 12-1-4 13-1-1**

State also the principle of the conservation of energy.

2. The laws of the simple pendulum are summarized in the formula $t=2\pi\sqrt{l/g}$. Explain clearly the meaning of each symbol in the formula. **Pendulum.**

If the frequency of oscillation of a pendulum is 98 per minute at a place where $g=980$ cm. per second per second, find the length of the pendulum.

3. State Archimedes' principle, and explain how it will enable you to identify a given piece of pure metal. **Archimedes' Principle 12-1-3 14-1-3**

How would you determine the specific gravity of a liquid?

4. A given quantity of gas is allowed to expand to 1·5 times its original volume. What will be the pressure it will exert, if it was originally at a pressure of 750 millimetres of mercury, the temperature remaining constant throughout? **On Boyle's Law.**

Describe an experimental arrangement by which your result may be verified.

Calorimetry.

5. Ten grammes of water at 70°C. are mixed with 5 grammes of water at 0°C., what will be the final temperature?

If the five grammes of water at 0°C. are replaced by an equal amount of ice at 0°C., what will be the final temperature?

The water equivalent of the calorimeter and stirrer is 1·3, and the latent heat of fusion of ice is to be taken equal to 79.

Expansion of a liquid.

6. Distinguish between real and apparent expansion in the case of liquid.

The coefficient of expansion of mercury is $\frac{1}{5550}$. If the bulb of a mercurial thermometer is 1 c.c., and the section of the bore of the tube 0·001 sq cm., find the position of the mercury at 100°C, if it just fills the bulb at 0°C. [Neglect the expansion of glass.]

Max. press. of water vapour 10-1-6

7. What is meant by 'maximum pressure of water vapour'? How can it be measured at ordinary temperatures?

Boiling Pt. of a liquid.

Water can be made to boil at all temperatures. Indicate the conditions that are, in general, necessary.

Vel. of Sound 12-1-8

8. Explain how you would determine the velocity of sound in air.

If the length of an open organ pipe sounding its fundamental note is one metre, find the frequency of the note. [Velocity of sound at the temperature of the experiment, 320 metres per second.]

Vibration of string.

9. State the laws connecting the frequency of the note emitted, and the length and tension of the vibrating sonometer string; and explain how you would verify the laws experimentally.

SECOND PAPER.

Only SEVEN *questions are to be attempted.*
The questions are of equal value.

1. Define index of refraction. State the condition for total reflection. Total Reflection 12-II-1

A rod is partially dipped into a basin of water. Explain, by means of a diagram, the appearance presented.

2. Describe a simple form of spectroscope, Spectroscope

Classify the various types of spectra that may be obtained, illustrating each type by an example. Types of spectra.

3. A rod is moved from a great distance along the principal axis of a double convex lens till it is very near the lens. Image by a Convex lens 12-II-3

Explain by means of typical diagrams how the image changes.

4. Describe a compound microscope. Explain by means of a diagram how the magnification is produced. Microscope 12-II-4 15-II-4

5. State the laws of action between magnet poles Laws of Magnetic action.

Two North poles repel one another with a force of 2·4 dynes when their distance apart is 2 cm. What will be their distance apart when the force is 3 6 dynes? Find also the repulsive force when their distance apart is 3 cm.

6. Given a piece of soft iron rod. Describe methods of magnetizing it. How would you test the induced polarity? How does it depend on the magnetizing agents employed. Magnetisation 11 IIB 6

7. Explain the action of (*a*) the electrophorus, (*b*) the gold-leaf electroscope. Electrophorus 12-II-6 14-II-5 electroscope 13 II-5

Condenser.

8. *A* and *B* are two insulated metal plates constituting a parallel plate condenser. *B* is connected to a gold-leaf electroscope. Describe the successive actions in the electroscope, when—

(*a*) *A* is charged positively ;
(*b*) *B* is momentarily connected to *A* ;
(*c*) *B* is momentarily connected to earth ;
(*d*) *A* is made to approach *B* ;
(*e*) A slab of glass is interposed between *A* and *B*.

Indicate the nature of the electrification of *B* at each step.

Laws of electrolysis 09-II-4 Polarisation 09-II-10

9. State the laws of electrolysis.

Explain, with an illustration, the effect of polarization on the constancy of a voltaic cell.

Eletro-dynanics.

10. Describe an arrangement for producing continuous rotation of a wire carrying current when placed in a magnetic field. How is the direction of the current related to the field?

Electro-magnetic Induction 09 II.5 11 IIB 4 13.II 10 14.II.9 15.II.9.

11. What is an induced current? Describe simple experiments which typically illustrate the production of induced currents.

ANSWERS.

FIRST PAPER—1916.

1. A force is said to do work when its point of application moves *in* the direction in which the force acts.

When the point of application moves in a direction *opposite* to that of the force, work is said to be done *against* the force.

If a heavy body falls to the ground, its weight does work. If we lift it up again we must do work against its weight.

The work done is measured by the product of the force and the distance through which its point of application moves in the direction of the force.

Energy is the capacity for doing work. A body in motion is able to do work against an opposing force until it comes to rest. A body may also possess energy in virtue of its position or of the configuration of its parts. Thus a body at a height can do work when allowed to fall down; again a compressed string in a clock supplies the energy of driving the clock.

For transformation of energy and conservation of energy see answers to *Q. 1-I-11* and *Q. 4-I 12*.

2. In the formula for the oscillation of a simple pendulnm. viz.,

$$t = 2\pi\sqrt{l/g}.$$

t is the period of oscillation, *i.e.* the time taken by the pendulum to complete one full oscillation, or the shortest time taken to come back to its initial position in the same phase of its motion.

l is the length of the pendulum measured form the point of suspension to the point of oscillation which is approximately given by the centre of gravity of the bob.

g is the acceleration due to gravity, measured in cms. per sec per sec. (approx. value, 980) or in feet per sec². (approx value, 32.)

π is 3·1415.

In the example given,

$$t = 60/98 \text{ sec.}$$

and $$g = 980 \text{ cms. per sec per sec.}$$

Substituting in the formula given above for t.

we have $60/98 = 2\pi\sqrt{l/980}$

whence $$l = \frac{98 \times 60 \times 60}{98 \times 98 \times 4 \times 9{\cdot}87} = \frac{4500}{49 \times 9{\cdot}87}.$$

$$\begin{aligned} \text{Now log. } 49 &= 1{\cdot}690 \\ \text{log. } 9{\cdot}87 &= \underline{\ {\cdot}994} \\ &\quad 2{\cdot}684 \\ \text{log. } 4500 &= \underline{3{\cdot}653} \\ &\quad 0{\cdot}969 = \text{anti log. } 9{\cdot}30. \end{aligned}$$

$$l = 9{\cdot}30 \text{ cm.}$$

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To distinguish a metal from its alloy see the answer to *Q. 3-I-12.*

For the determination of specific gravity of a liquid see *De.—Prac. Physics—page 105.*

4. Here as the gas expands under constant temp., we can apply Boyle's Law, viz.

$$PV = P'V'$$

Here $750 \times V = P' \times (1\cdot5\ V)$.

Whence $P' = 500$ m.m.

The result may be verified by using a Boyle's Law apparatus (as is commonly used in the laboratory (for figure see *De.—Prac. Physics Fig. 57, page 113.*) in which a quantity of dry air is enclosed.

Let the atmospheric pressure as obtained from a barometer be π. Adjust the position of the open tube so that the difference in the mercury levels in the closed and the open arms=the difference between the atmos. press π and the reqd. pressure 750.

Now the pressure of the enclosed air is 750. At this stage, note the length l of the enclosed air.

Lower the open arm until l', the new length,$=1\ 6 \times l$; as the tubes are of uniform cross section the change of volume is proportional. Now determine the pressure of the gas.

5. In the example given let t be the final temp.

Then, heat given out by 10 gms. of water in falling from 70°C to t $= 10 \times (70-t)$,

Heat absorbed by 5 grms. of water at 0°C in rising to $t°C = 5 \times (t-0)$..... (1)

Heat absorbed by calorimeter and stirrer

$$= 1\cdot3 \times t \quad \ldots \quad \ldots\ldots \ldots(2)$$

But heat lost = heat gained.

$\therefore$ $10 \times (70-t) = 1\cdot3\ t + 5\ t.$, whence $t = 42°9$ C

In the second case, in addition to (1) and (2) above, we have to take account of the heat absorbed by 5 grms. of ice at 0°C in being converted to water at 0°C. and this is

$$=5 \times 79 = 395 \text{ units.}$$

Hence $10 \times (70-t) = 6\cdot3t + 395$.

Whence $t = 18°7$C.

6. For distinction between real and apparent expansion of a liquid—See *Glazebrook. Heat. Art 76.*

In the example given, we have

$$V_t = V_0 (1+\gamma t)$$

Here $V_0 = 1$cc., $t = 100^\circ$C and $\gamma = 1/5550$

$\therefore$ $V_t = 1{\cdot}0182$ approx.

Of this volume, the portion 0·0182 occupies the bore of the tube and is of length 0·0182/·001 *i.e.* 18·2 cms. from the bulb of the tube. (The expansion of glass is here neglected.)

7. A liquid gives off vapour from its surface at all temperatures and this vapour behaves like a gas and exerts pressure.

Also when sufficient liquid is present to saturate a closed space with its vapour, the pressure of the vapour attains a maximum value, which is constant for a given liquid at a given temp.

The maximum pressure of water vapour at a temperature can be measured by introducing a sufficient quantity of water into the torricellian space of a barometer tube and noting the diminution in the height of mercury caused by the pressure of the water vapour formed. (*See Glazebrook, Heat Expt 36.*)

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In the case of an open pipe sounding its fundamental, we have

$$V = 2nl$$

where V is the vel of sound, n is the frequency of the note and l the length of the tube.

Hence $322 = 2 \times n \times 1.$

Or $n = 160.$

9. For the laws of vibration of a sonometer string and their verification; *See De Sound Art* 60.

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1. The index of refraction of a substance is a constant measured by the ratio of the sine of the angle of incidence to the sine of the angle of refraction, when a ray passes from vacuum to that substance. (*See Glazebrook, Light Art. 33*).

A ray can always pass from a rarer to a denser medium but the converse is not always true. When a ray in a denser medium strikes the surface of separation at an angle greater than the critical angle for the media concerned, it is not refracted out but is totally internally reflected. (*See Glazebrook Light, Arts 37 38*).

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1. Spectrum of an incandesent liquid or solid—this is a continuous band extending from red towards the violet as the temp. of the substance is gradually raised. The spectra of lime light or of an incandesent lamp etc. are examples of this.

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3. Absorption spectra—This kind occurs when a spectrum is interspersed by dark lines or spaces due to absorption of some of the rays during their passage through an intervening medium. The solar spectrum is an example of this kind and it contains many dark (absorption) lines. (*See Glazebrook, Light, Arts 117-19*).

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4. For the description and diagram of a compound microscope —*See Glazebrook, Light. Art 101.*

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4. For the description and diagram of a compound microscope —*See Glazebrook, Light. Art 101.*

5. The laws of action between magnet poles are simply that like poles repel and unlike poles attract and the force exerted between two magnets m and m' and separated by a distance r is mm'/r^2

In the example. given, we have

$$2.4 =$$

And $$= \frac{mm}{kr^2}$$

whence $r^2 = 8/3$ or $r = \sqrt{8/3}$.

Again, in the second case

$$2{\cdot}4 = \frac{mm'}{4}$$

$$F = \frac{mm'}{9} = 1.07 \text{ dynes, approx.}$$

6. As the rod given here is of soft iron, it can only be magnetised by putting it inside a coil of wire carrying a current; as long as the current passes, the rod is strongly magnetised but in the absence of the magnetising force it can retain very little of its magnetism.

The nature of the induced polarity can be tested by the action of one end of a rod on the N-pole of a magnet needle brought near to it.

In the Electric method, if the direction of the current in the turn of wire at one end is clockwise that end is seen to acquire a south seeking polarity. In the case where the direction of the current is anti-clockwise the end attains a north-seeking polarity. When a magnet is used as the magnetising agent the induced polarity at one end of the rod where the bar leaves it, is opposite to that in the end of the bar nearest the rod. (Also *See the answer to Q 6-II-11*).

7. For the action of (*a*) the electrophorus and (*b*) the gold-leaf electroscope. (*See Poyses pp. 87-91.*)

8. (*a*) When A is charged positively, it induces negative on the face of B nearest to A while free positieve charge travels to the outer side of B and causes the leaves of the electroscope to diverge.

(*b*) When A is momentarily connected to B the capacity of the system is very much diminished, the condensing arrangement being absent. As the charge remains the same, its potential is increased, which is indicated by the greater divergence of the leaves.

(*c*) When B is momentarily earth-connected. free positive charge on it escapes to the earth, and the leaves of the electroscope collapse.

(*d*) When A is made to approach B further induction takes place and the leaves of the electroscope diverge with free positive charge as in case (*a*).

(*e*) When a slab of glass is interposed between the two, the capacity of the system increases and the charge remaining the same, the potential decreases and the divergence is diminished.

9. The laws of Electrolysis are summed up in the formula $w=zct$ according to which w, the wt. of the ion deposited at the cathode, varies with the strength of the current c, the time of action t and the electro-chemical equivalent z of the ion liberated. (*See Poyser, page 272.*)

In an ordinary Voltaic cell, consisting of a copper plate, an amalgamated zinc rod and dilute sulphuric acid, the current generated soon falls in intensity due to what is called polarisation in the cell. Hydrogen bubbles arising out of the action of acid on the zinc accumulate on the copper plate and weakens the current by

(1) Offering resistance to its passage as gases are very bad electric conductors.

(2) By setting up an opposite *E. M. F.* due to which a current passes from Hydrogen bubbles towards the zinc. (*See Poyser, page 190.*)

10. For a complete answer (*See Poyser, page 240 Expt. 164.*)

11. A current is said to be induced in a coil when it is generated in the coil owing to the presence of a current in a neighbouring coil or due to a magnet placed near it.

For typical experiments (*see Poyser, page 285-6.*)

INDEX.

GENERAL PHYSICS.